SPACE PROCESSING APPLICATIONS PAYLOAD EQUIPMENT STUDY

VOL. II A. EXPERIMENT REQUIREMENTS

DPD NO. 40
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JULY 1974

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FOREWORD

Phase II documentation prepared for the Requirements and Concepts for Space Processing Payload Equipment Study under Contract NAS 8-28938 resulted in a three-volume report. These volumes are as follows:

Volume I. Executive Summary
Volume II. Technical
- IIA. Experiment Requirements
- IIB. Payload Interface Analysis
- IIC. Data Acquisition and Process Control
- IID. SPA Kit
- IIE. Commercial Equipment Utility

Volume III. Programmatics and Payload Accommodation

Volume II, Technical, is published as five sub-volumes in order to facilitate presentation of topical groupings of data.

Phase I documentation was previously documented in 1973 as three volumes under the title, Requirements and Concepts for Materials Science and Manufacturing in Space.

One feature of this study has been the close association between the NASA Shuttle Sortie Working Group on Materials Science and Manufacturing in Space and the study contractor, TRW Systems Group. The NASA-MSFC study COR, Mr. Kenneth R. Taylor, has provided TRW Systems Group with working group documentation and, in turn, has coordinated study task results into the activities of the working group.

The TRW Systems Group personnel who assisted in the preparation of Volume IIA are listed below:

Ms. A. G. Smith
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EXPERIMENT REQUIREMENTS

1. SUMMARY

The task of defining payload equipment necessary to process materials in space necessitates that an analysis be made regarding the experimental areas to be accommodated. Continued efforts to review and refine the equipment functional requirements is being made in the area of Space Processing Applications.

This volume deals with the review that was performed during the current study, which was concentrated in two areas: review of recent literature and interviews with current investigators.

A review of newly received literature was made to ascertain if any research areas were omitted from consideration during the initial study. In total, 18 additional experiment areas were identified and found to be appropriate for early mission studies. These included five (5) in biological applications, one (1) in fluid chemistry, two (2) in crystal growth, four (4) in glass technology, two (2) in metallurgical processes and four (4) in fluid physics. In order to be able to accommodate all of these new areas it was found that a minimal number of additional equipment was needed. Added to the equipment list in order to perform additional experiments in the research area of biologicals was a cryoprecipitator. A xenon arc-image heater was added for the areas of glass technology and metallurgical processes. In the area of fluid physics one additional item was defined - a stroboscope. These additions to the payload equipment list are minimal when it is considered that almost 100 items had been specified previously.

An experimenter's questionnaire was prepared and distributed to 32 investigators currently involved in experimentation in materials processing. A total of 16 replies were received, all in the research areas of metallurgical processes, crystal growth and fluid physics. An examination of the replies revealed that the anticipated requirements are generally consistent with those specified in the initial study. In the area of sample sizes, however, there was indication that some experimenters may be specifying too large a sample for accommodation in initial studies.

As an example, the largest total sample volume specified in this study was between 0.03 - 0.23 m^3 (1 - 8 ft^3) for the drop positioning and dynamics experiment; whereas, the largest anticipated volume in the initial study was only 0.001 m^3 (0.35 ft^3). A compromise will be necessary with regard to this subject as well as others that may arise in the future.

The results of the questionnaires that were submitted are included in this report as short, one-to three-page-long summaries. No new equipment was specified by the experimenters beyond what was already anticipated.

2. INTRODUCTION

2.1 OBJECTIVES

This document represents the results of Task 1 of the "Space Processing Applications Payload Equipment Study" performed for NASA's George C. Marshall Space Flight Center under Contract No. NAS 8-2[illegible]938. The objective of the Task 1 activities was to perform a review and an update of the SPA research equipment requirements and specifications that were derived in the first year-long study. Those results were documented in Volume IIA, "Experiment Functional Requirements", Volume IIB, "Equipment and Instrument Identification", and Volume IIC, "Experiment/Equipment Review" of the "Requirements and Concepts for Materials Science and Manufacturing in Space Payload Equipment Study" report.

The requirements and exemplary experiments contained both in the previous report and in this document are not intended to be taken as representing a NASA-approved SPA experiment program.

The activity on this task was broken down into the subtask [illegible] are listed below:

- Review experiments identified in initial study.
- Investigate new experiments and their functional requirements.
- Assess any new experiment functional requirements against capability of current payload equipment.
- Consolidate functional requirements of any new experiments with experiment requirements from the initial study.
- Identify any additional equipment items not specified previously.
- Derive basic engineering data for each additional item of payload equipment.

2.2 ASSUMPTIONS AND GUIDELINES

The assumptions and guidelines listed on the following page have been followed throughout the discharge of the Task 1 activities

a. The initial operating capability (IOC) date for Shuttle missions is assumed to be 1980.

b. Early mission efforts will be concerned with establishing and conducting an ongoing research and development program which, in turn, will lead to the ultimate goals of producing economically viable space products.

c. The Shuttle/Spacelab initially will provide frequent and repetitive 7-day missions to provide for rapid evolvement of the required technology.

d. There will be a minimum of in-orbit data evaluation. Most data obtained will be stored until return to Earth for evaluation.

e. All in-orbit activities will be executed in a shirt-sleeve environment.

f. All processes and equipment mentioned will be non-hazardous to the crew members.

g. To the greatest degree possible, experiment areas chosen should be doable utilizing commercially available equipment in order to minimize development costs.

h. Experiment areas chosen should be such that the equipment requirements will be common to several different areas in order to build a multi-use catalog of apparatus.

2.3 SYNOPSIS OF PREVIOUS DOCUMENTATION

In order to have a baseline of information with which to make a comparison, a synopsis of the results from related tasks in the first year-long study is included in this report.

2.3.1 Experiment Functional Requirements

The purpose of this task of the previous study was to document an initial set of functional requirements that need to be satisfied in order to do experiments in the materials sciences in space. This documentation was based upon previously completed studies and then-ongoing programs. The equipment requirements were, and still are, constrained to use in frequent-flight, seven-day-long, relatively small, payload assignments in either dedicated or shared Space Shuttle/Spacelab missions. This constraint necessitated that a distillation be performed on the many

candidate experiments that existed in order to reduce to a minimum crew participation and in-flight experiment evaluation. Furthermore, a screening of the potential experiments was needed in order to list the experiments' functional requirements. This list was necessary in order to determine the extent of compatibility with early Shuttle missions and also to develop a comprehensive inventory of equipment with enough flexibility to be used in different modes and complete enough to meet the needs of the potential investigators.

The starting point for the investigation was the six major experiment classes that were identified by NASA for potential study in the SPA program. These are listed below:

- Biological Applications
- Chemical Processes in Fluids
- Crystal Growth
- Glass Technology
- Metallurgical Processes
- Physical Processes in Fluids

Instead of specifying exact experiments to be performed in each of these research and development (R&D) areas as the basis for determining equipment needs, it was decided to instead specify process areas in which groups of experiments may be found. These process areas, therefore, should require equipment that is common to several experiments in that area. It was determined that the R&D categories encompassed the following five process areas:

- Crystal Growth - There are three broad categories of crystal growth that are considered most conducive to in-space processing. These are growth from a melt, growth in solution and growth from a vapor phase. The experimental procedures involved in these areas will be strongly dependent upon the problems of positioning, stirring and shaping the melts and solutions under weightless conditions.

- Purification/Separation - This process area will benefit from in-space processing because of greatly reduced buoyancy and convective effects. The production of

super-pure materials becomes possible when one can use high temperatures, ultra-high vacuum and containerless samples - especially in multipass, molten-zone refining of ultra-pure elements. Also included in this process area are low temperature separations of biological materials such as living cells, serums, vaccines and other macromolecular materials of potential medical or pharmaceutical utility.

- Mixing - This process area includes those procedures where homogenization of materials is a problem on Earth due to density differences that cause segregation problems upon solidification. This is apparent in two specific areas: immiscible materials and composite materials. On Earth, inhomogeneities are caused due to variations in density, compatibility and surface tension between the separate components.

- Solidifications - There are three areas of investigation that are included under this process area. These include the following: controlled or directionally solidified eutectic structures; preparation of glasses; supercooling and homogeneous nucleation.

- Process in Fluids - This area consists of two types of processes as they occur under weightless conditions. Chemical processes which are concerned with reactions and rates at which these occur and physical processes which are concerned with physical and thermodynamic phenomena (not changes of state or compositions). The condition of very low gravity will permit evaluations that have never before been possible in these fields.

Naturally, some experiments can be classified under more than one process area, depending upon one's point of view. This does not present a problem, however, if one classifies it according to its major objective.

In setting down the functional requirements of the experiment areas it was intended to call out requirements that reflect the needs of R&D types of activities. This affects certain areas of interest such as sample sizes, heating requirements, positioning requirements, enclosure sizes and fluid supply sizes. Ranges of values that were called out were intended to be typical, not limiting or final. This allows for modification of requirements as more knowledge and experience is gained up until the actual time of collecting and assembling hardware together for flights. It must be emphasized also that many times the equipment capabilities can greatly exceed the anticipated requirements with no decrease in efficiency

and with no additional costs.

The results of the initial study were consolidated into four matrix charts that show the following four types of information as a function of the individual process areas: process data, process methods, measured quantities and controlled quantities. These charts are included here as Tables I A - D to summarize the results of that initial portion of the first study.

These charts list both tacit and specific functional requirements that have been identified to support the various research process areas to be studied in space. Designs consistent with automated and/or semi-automated operations have not been listed as requirements but are necessary for most of the equipment. Such designs satisfy the need for all of the following. reproducibility of performance in experimental activities, minimization of crew participation, exploitation of pallet or shared-mission opportunities and development of capabilities which ultimately support manufacturing activities.

Initial designs can probably incorporate features that permit automatic and/or manual operation. The automated control functions may be provided by use of either a process computer or a programmable controller which can accommodate the desired procedures.

The charts are organized vertically along the research process areas previously discussed and horizontally by the basic areas of process data, process methods, measured quantities and controlled quantities. The values listed represent generalized capabilities supporting more than one particular experiment. The items under the heading of Process Data are self-explanatory with the possible exceptions of "displacement rate" and "heat input". In crystal growth the displacement rate pertains to the rate at which a crystal is pulled from a melt or the motion of the molten zone along the length of material undergoing floating zone melting. The values shown for heat input are considered typical of the energy required <u>only</u> to bring the specimen to the required temperature. It does not allow for any inefficiencies in the heating method or for any heat loss to the chamber enclosure.

TABLE IA: FUNCTIONAL REQUIREMENTS - PROCESS DATA

PROCESS DATA	CRYSTAL GROWTH			PURIFICATION		MIXING		SOLIDIFICATION			PROCESSES IN FLUIDS	
	SOLU-TION	MELT	VAPOR	BIOLOG-ICALS	ELE-MENTS	COM-POSITES	IMMISC-IBLES	EUTEC-TICS	GLASS	HOMO. NUCLE-ATION	PHYS-ICAL	CHEM-ICAL
SAMPLE SIZE												
VOLUME (cm^3)	100-1000	50-500	1-5	35-1000*	25-100	10	1-10	5-10	1-2	1-2	50	200
TEMPERATURE (°C)												
<20				●								
20-300	●	●	●			●	●	●			●	●
300-1600	●	●	●		●	●	●	●	●	●		
1600-2600		●			●				●			
>2600									●			
HEAT INPUT (KJ)												
0-20		●	●								●	●
20-40	●	●			●		●	●	●	●		
40-200					●	●	●	●				
TEMPERATURE GRADIENT (°C/cm)		2-50	2-50		5			2-500			●	
COOLING RATE (°C/min)	0.1	0.1						●	1-1000	1-100	●	
ATMOSPHERE												
VACUUM		●	●		●	●	●	●	●	●	●	●
INERT GAS	●	●	●		●	●	●	●		●	●	●
OXIDIZING	●	●	●						●			
DISPLACEMENT RATE (cm/min)		.001-5			.05-1			.1-1			●	
ROTATION RATE (RPM)		1-60									●	
FLOW RATE (cm^3/min)			10	20							●	●
VOLTAGE GRADIENT (v/cm)				2-100								
pH				7-9								●

*INCLUDES BUFFER SOLUTION

TABLE IB: FUNCTIONAL REUQIREMENTS - PROCESS METHODS

PROCESS METHOD	CRYSTAL GROWTH			PURIFICATION		MIXING		SOLIDIFICATION			PROCESSES IN FLUIDS	
	SOLU-TION	MELT	VAPOR	BIOLOG-ICALS	ELE-MENTS	COM-POSITES	IMMISC-IBLES	EUTEC-TICS	GLASS	HOMO. NUCLE-ATION	PHYS-ICAL	CHEM-ICAL
HEATING												
RESISTANCE FURNACE	●	●	●		●	●	●	●	●	●	●	●
INDUCTION	●	●	●		●				●	●		
ELECTRON BEAM					●				●			
LASER/INDUCTION									●			
QUARTZ TUBE												●
COOLING												
ACTIVE	●	●	●	●	●	●	●	●	●	●	●	●
PASSIVE	●	●	●		●	●	●	●	●	●	●	●
LIQUID DEPLOYMENT	●										●	
POSITIONING	●	●	●		●				●	●	●	●
CONTAINMENT	●		●	●		●	●	●			●	●
MIXING, AGITATION												
CONTACT	●		●			●	●				●	●
NONCONTACT	●	●	●			●	●		●	●	●	
DISPLACEMENT												
CONTACT								●			●	
NONCONTACT		●	●		●						●	
FLUID FLOW				●				●			●	
ELECTRO-, DIELECTROPHORESIS				●								

TABLE IC: FUNCTIONAL REQUIREMENTS - MEASURED QUANTITIES

MEASURED QUANTITY	CRYSTAL GROWTH			PURIFICATION		MIXING		SOLIDIFICATION			PROCESSES IN FLUIDS	
	SOLU-TION	MELT	VAPOR	BIOLOG-ICALS	ELE-MENTS	COM-POSITES	IMMISC-IBLES	EUTEC-TICS	GLASS	HOMO. NUCLE-ATION	PHYS-ICAL	CHEM-ICAL
TIME	●	●	●	●	●	●	●	●	●	●	●	●
TEMPERATURE												
CONTACT	●		●	●	●	●	●	●			●	●
NONCONTACT	●	●	●		●				●	●	●	●
TEMPERATURE GRADIENT	●	●	●		●			●			●	●
COOLING RATE	●	●	●		●			●	●	●	●	●
ENVIRONMENT	●	●	●		●							
PRESSURE	●	●	●	●	●				●	●	●	●
POSITION	●	●	●		●			●	●	●	●	●
DISPLACEMENT												
CONTACT		●			●			●				
NONCONTACT		●			●						●	
OSCILLATION	●	●			●				●	●	●	
MIXING						●	●		●		●	●
HEAT FLUX	●	●	●		●			●		●		
FLOW RATE			●	●							●	
VOLTAGE GRADIENT				●								
CURRENT DENSITY				●								
POWER	●	●	●	●	●	●	●	●	●	●	●	●
ACCELERATION	●	●	●	●	●	●	●	●	●	●	●	●
PARTICLES INHOMOGENEITIES, ETC.	●	●		●					●	●	●	●
SEPARATION VELOCITY				●								●
pH				●								●

TABLE ID: FUNCTIONAL REQUIREMENTS - CONTROLLED QUANTITIES

CONTROLLED QUANTITY	CRYSTAL GROWTH			PURIFICATION		MIXING		SOLIDIFICATION			PROCESSES IN FLUIDS	
	SOLU-TION	MELT	VAPOR	BIOLOG-ICALS	ELE-MENTS	COM-POSITES	IMMISC-IBLES	EUTEC-TICS	GLASS	HOMO. NUCLE-ATION	PHYS-ICAL	CHEM-ICAL
PROCESS TIME	●	●	●	●	●	●	●	●	●	●	●	●
TEMPERATURE	●	●	●	●	●	●	●	●	●	●	●	●
TEMPERATURE GRADIENT	●	●	●		●		●	●		●	●	
COOLING RATE	●	●	●		●		●	●	●	●	●	●
POSITION	●	●	●		●			●	●	●	●	●
DISPLACEMENT RATE		●			●			●			●	
OSCILLATION	●	●			●				●	●	●	
MIXING						●	●		●		●	●
FLOW RATE			●	●							●	●
VOLTAGE GRADIENT				●								
pH				●								●

The features listed under Process Methods are of a general nature. Under "heating" several different methods have been identified for the experiment samples. The ones indicated for a given process are those which are considered to be most appropriate on the basis of heating requirements, temperature ranges and heating efficiency. Some flexibility in heating methods is anticipated.

The "cooling" requirements have been specified as either active or passive. Active cooling will require either positive heat rejection control or active control of heating and/or cooling to produce a given cooling rate.

"Liquid deployment" is concerned with placement of a liquid in a position suitable for the liquid to be brought under the control of a containerless position control system.

"Position control" is indicated for any process involving a containerless or contact-free function. All examples considered so far also require active sensing of the location of the specimen in the enclosure or heat zone. In contrast to positioning, "containment" is taken to mean fixing the location, position or orientation of a sample through physical contact with it.

The remaining portions in this chart and the parameters listed under the general headings of Measured Quantity and Controlled Quantity are all self-explanatory and need no explanation beyond what has been given.

2.3.2 Equipment and Instrument Identification

The purpose of this task was to define more fully the specific items of equipment needed to fulfill the functional requirements of the previous section. An analysis was made to classify the equipment into broad categories according to function and also to assess the commonality of use among the R&D categories and among the modular equipment subelements.*

In total, 95 equipment items were listed for which summary data was compiled. A total of 36 specifications were written encompassing 55 of

*These equipment subelements are explained fully in the previous report issued under the same contract number.

the equipment items. These specifications included sections on the anticipated usage, the functional requirements and rationale and the specifications or criteria. A list of the equipment items along with their commonality and summary data is shown in Table II.*

2.3.3 Experiment/Equipment Review

As a review of the work that had been completed previously, a task was initiated the purpose of which was to add or delete experiments and/or equipment items as necessary. Two tables of experiments were prepared at that time: one listing the experiment areas that had been discussed in Volume IIA and one listing new experiment areas. These two have been hybridized into one in Table III which lists the experiment areas according to R&D category.

Also included as a part of that volume was a list of additional equipment items needed and these few items have been incorporated into Table II.

* Also included in the listing are items that were added later in the study.

FOLDOUT FRAME

TABLE 2.

A GUIDE TO SPACE PROCESSING PAYL

SPA EXPERIMENT REQUIREMENT SUMMARY

EQUIPMENT CATEGORY	EQUIPMENT ITEM	R & D CATEGORY: BIOLOGICAL APPLICATIONS	CHEMICAL PROCESSES IN FLUIDS	CRYSTAL GROWTH	GLASS PREPARATION	METALLURGICAL PROCESSES	PHYSICAL PROCESSES IN FLUIDS	SUBELEMENT (COMMONALITY): BIOLOGICAL	CORE	FURNACE	GENERAL PURPOSE	LEVITATION	SUMMARY DATA: NO. REQD.	DIMENSIONS X (M)	Y (M)	Z (M)	WT. KG	VOL. M³	POWER (WATTS) PEAK	SUS.	DATA BPS
ATMOSPHERIC COMPOSITION																					
	FLUID SUPPLY SYSTEM C10E	●	●	●	●	●	●		●				1	.61	61	1 2	34.0	4*7	-	-	-
	GAS CHROMATOGRAPH G16E, L34E		●	●	●	●					●	◉	1	.91	91	.30	22.7	.248	300	300	02
	HIGH VACUUM PUMP F25E, L45E			●		●				◉		◉	2	.30	.30	.46	22 7	041	100C	50	40
	MOLECULAR SIEVE B27E, F28E, G28E, L46E	●		●		●		●		◉	●	◉	2	15	15	30	4.5	007	-	-	-
	RESIDUAL GAS ANALYZER F12E, L35E			●	●	●				●		●	1	.24	.*9	.52	34.0	.061	260	250	02
	VACUUM/PRESSURE MEASUREMENT UNIT F26E, G17E, L36E			●		●				◉	●	◉	1	.24	.49	.52	6.8	.061	100	50	02
	VACUUM/PRESSURE REGULATOR F24E, G18E, L37E			●		●				◉	●	◉	1	.24	49	52	9 1	.061	100	50	02
BIOLOGICAL PROCESS EQUIPMENT	CONTINUOUS FLOW ELECTROPHORETIC COLUMN B11E	●						◉					1	37	1.22	.10	4 52	045	*	*	-
	DIALYSIS UNIT B9E	●						●					1	.30	30	.30	4 5	.027	100	100	01
	DISSOLVED OXYGEN ANALYZER B19E	●						◉					2	23	21	.34	7 7	016	15	15	10
	FLOW METER B17E	●						◉					4	.03	03	09	.45	000	10	10	10
	FRACTION COLLECTION SYSTEM B16E	●						◉					1	37	09	45	9 0	015	50	50	01
	ISOELECTRIC FOCUSING UNIT B31E	●						●					1	27	03	03	1 36	000	*	*	-
	GAS ELIMINATION SYSTEM B13E	●						◉					2	.15	15	24	2 3	005	50	50	10
	LYOPHILIZATION UNIT B16E	●						●					1	.76	55	37	90 6	155	600	200	01
	PH MONITOR B15E, B13E	●	●					◉			●		1	.37	46	.30	10 0	051	20	20	01
	PUMPS & METERING B10E	●						◉					2	18	18	45	10 0	015	-	100	10
	RECIRCULATING FLUID INCUBATOR B5E	●						●					1	90	60	60	9 0	.374	200	10	01
	REGULAR BUFFER SUPPLY & ELECTROLYTE SUPPLY TANK B14E	●						◉					4	.15	15	.15	1 36	.003	-	-	-
	STATIONARY ELECTROPHORETIC COLUMN B12E	●						●					5	27	03	03	1 36	000	*	*	-
CONTAINERLESS POSITION CONTROL EQUIPMENT	CONTAINERLESS POSITION CONTROL SYSTEM																				
	ACOUSTIC TRANSDUCER & DETECTOR L16E		●		●	●	●					◉	1	.30	30	.30	11 3	.027	-	200	10K
	ELECTROMAGNETIC POSITIONING COILS & DETECTOR L14E		●	●	●	●	●					●	1	.30	30	30	11 3	027	-	200	10K
	ELECTROSTATIC POSITIONING PROBES & DETECTOR L15E		●	●	●	●	●					●	1	30	30	30	11 3	.027	-	200	10K
	GAS JET PROBES & DETECTOR L17E			●	●	●						●	1	30	30	.30	11 3	027	-	200	10K
COOLING EQUIPMENT	COOLANT SUPPLY TANK B29E	●						●					1	21	42	42	4 5	037	-	-	-
	DIRECTIONAL SOLIDIFICATION UNIT F4E					●				●			1	30	46	.30	18 1	041	-	-	02
	FLUID COOLING/REFRIGERATION UNIT B1E	●						◉					1	1 34	.82	94	180 0	1 033	750	750	02
	SAMPLE COOLING CHAMBER F5E					●				●			1	30	.46	30	18 1	041	-	-	40
	SAMPLE STORAGE AND PRESERVATION OF BIOLOGICALS																				
	DEWAR B25E	●						●					1	54	34	30	22 7	136	-	-	-
	FREEZER B24E	●						●					1	54	84	.30	80 0	136	500	100	-
	REFRIGERATOR B23E	●						◉					1	54	84	.61	57 0	.277	250	50	-
DATA ACQUISITION AND CONTROL EQUIPMENT	DATA ACQUISITION UNIT																				
	DIGITAL CLOCK C1E	●	●	●	●	●	●		●				1	37	15	43	11 3	024	-	100	
	DIGITAL VOLTMETER C4E	●	●	●	●	●	●		●				1	37	15	43	18 1	.024	-	100	-
	MULTIPLEXER A/D CONVERTER C14E	●	●	●	●	●	●		●				1	52	18	49	27 2	045	-	100	-
	PRINTER (OUTPUT) C9E	●	●	●	●	●	●		●				1	.32	.30	43	22 7	048	-	400	-
	SCANNER PROGRAMMER C2E	●	●	●	●	●	●		●				1	37	15	43	9 1	024	-	20	-
	SET POINT CONTROLLER C5E	●	●	●	●	●	●		●				1	37	.24	43	22 7	038	-	100	-
	SIGNAL CONDITIONER C3E	●	●	●	●	●	●		●				1	52	34	49	27 2	087	290	35	-
	DATA CONTROL UNIT																				
	ANALOG (SCR) CONTROLLER C13E	●	●	●	●	●	●		●				1	52	37	49	15 9	.094	-	100	-
	DIGITAL STORAGE C12E	●	●	●	●	●	●		●				1	.52	.30	.49	18.1	.076	-	150	-
	INPUT/OUTPUT STAGE C7E	●	●	●	●	●	●		●				1	.52	.15	.49	18.1	.038	-	150	-
	OPERATOR CONTROL UNIT C8E	●	●	●	●	●	●		●				1	.52	.52	.49	27.2	.132	-	230	-
	PROCESSOR UNIT C6E	●	●	●	●	●	●		●				1	.52	.34	.49	27.2	.087	-	200	-
	STORAGE PERIPHERALS C16E	●	●	●	●	●	●		●				1	.52	.18	.49	15 9	.046	-	100	-
	TAPE INPUT C15E	●	●	●	●	●	●		●				1	.52	.18	49	22 7	046	-	120	-
	TELEPRINTER C11E	●	●	●	●	●	●		●				1	.52	.76	34	22 7	.134	-	120	-
	ELECTRO-OPTICAL IMAGING SYSTEM C17E																				
	AUTOMATIC PROCESSOR	●	●	●	●	●	●		●				1	.49	.18	.61	27.4	.064	200	-	-
	CCTV CAMERA	●	●	●	●	●	●		●				1	.23	.09	.09	[illegible]	[illegible]	-	30	-
	CAMERA CONTROL UNIT	●	●	●	●	●	●		●				1	.40	.15	.31	[illegible]	[illegible]	-	30	-
	FRAME STORAGE UNIT	●	●	●	●	●	●		●				1	.46	.09	.43	9.1	.018	-	25	-
	MONITOR	●	●	●	●	●	●		●				1	.46	.34	.52	20.7	.081	-	140	-
	SLOW SCAN SYNC & SWEEP	●	●	●	●	●	●		●				1	.46	.09	.09	2.3	.004	-	[illegible]	-
	NUCLEAR PARTICLE COUNTING UNIT G25E						●				●		1	.52	21	.49	22.7	.054	-	100	1K
	OSCILLOSCOPE C18E	●	●	●	●	●	●		●				1	.30	24	.46	13.6	.033	-	100	-
	TIME LAPSE/HIGH SPEED CAMERA G22E, L44E		●	●	●		●				◉	●	1	.30	30	.46	13.6	041	100	100	-

FOLDOUT FRAME 2

TABLE 2.

PAYLOADS FOR SHARED MISSIONS*

VOL. M³	POWER (WATTS) PEAK	POWER (WATTS) SUS.	DATA BPS
447		-	-
248	300	300	02
041	1000	50	40
007	-	-	-
.061	250	250	02
061	100	50	02
.6	100	50	02
.045	•	•	-
.027	100	100	01
016	15	15	10
000	10	10	10
015	50	50	01
.000	•	•	-
005	50	50	10
155	600	200	01
051	20	20	01
0 5	-	100	10
324	200	10	01
.003	-	-	-
000	•	•	-
027	-	200	10K
027	-	200	10K
027	-	200	10K
027		200	10K
037			-
041	-	-	02
1 033	750	750	02
041	-	-	40
136	-	-	-
136	500	100	-
277	250	50	-
.024	-	100	-
024	-	100	-
046	-	100	-
048	-	400	-
024	-	20	-
038	-	100	-
087	290	35	-
094	-	100	-
.076	-	150	-
.038	-	150	-
.132	-	230	-
.087	-	200	-
046	-	100	-
046	-	120	-
.134	-	120	-
.054	700	-	-
.002	-	30	-
.013	-	30	-
.018	-	125	-
.081	-	140	-
.004	-		-
.054	-	100	1K
.033	-	100	-
.041	100	100	-
	-	-	-

REVISED 5/22/74

REQUIREMENTS FOR COMBINATIONS OF MAXIMUM/MINIMUM EQUIPMENT SUBELEMENTS

SUBELEMENT COMBINATION (MINIMUM SUBELEMENT COMBINATIONS GIVEN IN PARENTHESES)	WEIGHT [9] (KG)	WEIGHT [9] (LB)	VOLUME [9] (M³)	VOLUME [9] (FT³)	POWER SUS. (KW) [8]	POWER AVERAGE (KW) [7]	POWER PEAK (KW) [6]	DURATION PER CYCLE AT AVERAGE POWER (HR) [5]	DURATION PER CYCLE AT PEAK POWER (HR)	AVERAGE ENERGY PER CYCLE (KWH) [4]	CYCLES PER MISSION	TOTAL EXPER'T ELAPSED TIME (HR) [3]	TOTAL HOURS PER MISSION (HR) [2]	TOTAL ENERGY PER MISSION (KWH) [1]
BIOLOGICAL (B)	809	1780	4.3	150	1.8	0.95	2.75	1.68	0.15	1.6	13	21.8	23.3	22
(MINIMUM-b)	(404)	(898)	(3.0)	(106)	(1.8)	(1.34)	(1.71)	(4.1)	(0.10)	(5.5)	(1)	(4.1)	(4.9)	(5.5)
FURNACE (F)	529	1160	2.8	100	5.0	4.22	11 3	3.75	0.20	15.8	16	60.0	61.8	254
(MINIMUM-f)	(181)	(401)	(1.1)	(39)	(1.9)	(2.84)	(10 7)	(4.5)	(0.5)	(12.8)	(1)	(4.5)	(5.2)	(12.8)
GENERAL PURPOSE (G)	586	1290	3.4	120	1.7	2 56	1.44	4.45	2.00	11.4	9	40.0	41.1	103
(MINIMUM-g)	(230)	(510)	(2.3)	(81)	(0.56)	(0.47)	(1.33)	(1.8)	(0.1)	(0.85)	(1)	(1.8)	(2.4)	(0.85)
LEVITATION (L)	1180	2600	4.3	169	6.0	5.05	14.0	3.66	0.30	18.6	12	44.2	47.0	224
(MINIMUM-l)	(282)	(627)	(1.9)	(67)	(2.12)	(3.16)	(4.56)	(3.8)	(1.0)	(12.0)	(1)	(3.9)	(4.4)	(12.0)
CORE (C)	518	1140	3.1	110	1.8	1.8	0.7	[10]	0.25	[11]	[11]	[11]	[11]	[11]
B+C	1330	2920	7.4	260	3.6	2.76	2 74	1 68	0.15	4.95	13	21.8	24.3	64.[illegible]
(b+c)	(922)	(2040)	(6.1)	(215)	(3.6)	(3.15)	(1.70)	(4.1)	(0.1)	(12.9)	(1)	(4.1)	(5.9)	(12.9)
F+C	1050	2300	5.9	210	6.8	6.03	11.3	3.75	0.20	2[illegible] 6	16	60 0	62 8	362
(f+c)	(699)	(1540)	(4.2)	(148)	(3.7)	(4.64)	(10.7)	(4.5)	(0.5)	(20.9)	(1)	(4.5)	(6 2)	(20.9)
G+C	1100	2430	6.5	230	3 5	4 36	1.44	4.45	2.00	19.4	9	4[illegible]	42 [illegible]	175
(g+c)	(748)	(1650)	(5.4)	(91)	(2.36)	(2.27)	(1.33)	(1.8)	(0.1)	(4 09)	(1)	(1.8)	(3.4)	(4.09)
L+C	1700	3740	7.9	279	7.8	7.20	13.6	3.68	0.30	25.2	12	44 2	48.0	303
(l+c)	(800)	(1770)	(5.0)	(177)	(3.92)	(4.95)	(4.57)	(3.8)	(1.0)	(18.8)	(1)	(3.8)	(5.4)	(18
B+F+C	1860	4090	10.2	360	6 2	5 18	12.1	2.62	0.20	14.6	29	81.8	86.1	424
(b+f+c)	(1100)	(2440)	(7 2)	(254)	(3.7)	(3.93)	(11.4)	(4.3)	(0.5)	(16 9)	(2)	(8.6)	(11.1)	(33.8)
B+G+C	1910	4220	10.8	380	3.5	3.85	1.95	2.81	2.00	10.8	22	61.8	65.4	238
(b+g+c)	(1150)	(2450)	(8.4)	(297)	(3.3)	(2.83)	(2.02)	(3.0)	(0.1)	(8.5)	(2)	(5.9)	(8.3)	(17.0)
B+L+C	2510	5530	12.2	429	6.8	5.54	15.3	2 64	0.30	14 6	25	66 0	71.3	365
(b+l+c)	(1200)	(2670)	(8 0)	(282)	(3.8)	(3.98)	(5.54)	(4.0)	(1.0)	(15.9)	(2)	(7.9)	(10.3)	(31.7)
F+G+C	1630	3600	9 2	330	5.3	5.35	12 0	4.00	0.2[illegible]	21.4	25	100	104	535
(f+g+c)		(2050)	(6.5)	(229)	(3 3)	(3.94)	(11.4)	(3.2)	(0.5)	(12.6)	(2)	(6 3)	(8.6)	(25.1)
F+L+C	2230	4900	10.7	379	7.2	6.36	14.4	3.73	0.30	23 7	28	104	110	664
(f+l+c)	(981)	(2170)	(6.1)	(215)	(3.8)	(4.74)	(10.6)	(4.2)	(0.5)	(19.9)	(2)	(8.3)	(10.6)	(39.8)
G+L+C	2280	5040	11.3	399	5.5	5.66	15.1	4.01	0.30	22 7	21	84.2	89 1	47
(g+l+c)	(1030)	(2280)	(7.3)	(258)	(3.5)	(4.11)	(5.41)	(2.8)	(1.0)	(11.5)	(2)	(5.6)	(7.8)	(23.0)
B+F+G+C	2440	5380	13.6	480	5.1	4.92	12.4	3.19	0.20	15.7	38	122	127	598
(b+f+g+c)	(1330)	(2950)	(9.5)	(335)	(3.5)	(3.60)	(11.7)	(3.5)	(0.5)	(12.6)	(3)	(10.4)	(13.5)	(37.8)
B+G+L+C	[illegible]0	6820	15.6	549	5.3	5.08	15.7	3.11	0.30	15.8	34	106	112	538
(b+g+l+c)	(1430)	(3180)	(10.3)	(364)	(3.5)	(3 72)	(5.80)	(3.2)	(1.0)	(11.9)	(3)	(9.7)	(12.7)	(35.8)
B+F+L+C	3040	6700	15.0	529	6.8	5.77	15.0	3.08	0.30	17.8	41	126	133	729
(b+f+l+c)	(1390)	(3070)	(9.1)	(321)	(3.8)	(4 27)	(11 0)	(4.1)	(0.5)	(17.5)	(3)	(12.4)	(15.5)	(52.6)
F+G+L+C	2810	6210	11.1	499	[illegible] 0	5.79	15.0	3.91	0.30	22.7	37	144	151	840
(f+g+l+c)	(1210)	(3180)	(8.4)	(297)	(3.6)	(4.29)	(11.0)	(3.4)	(0 5)	(14.6)	(3)	(10 1)	(13.0)	(43.8)

REMARK

[1] ADD THE 'TOTAL ENERGY PER MISSION' FOR EACH INDIVIDUAL SUBELEMENT TO THE ENERGY NEEDED BY THE CORE. THE CORE ENERGY IS DETERMINED BY ADDING 1HR. (FOR INITIAL AND TERMINAL OPERATIONS) TO THE RESPECTIVE 'TOTAL EXPERIMENT ELAPSED TIME' [3] AND MULTIPLYING THIS BY THE POWER LEVEL OF THE CORE (1.8KW).

[2] INCLUDES THE TIME REQUIRED FOR EXPERIMENT PREPARATIONS, OPERATIONS AND POST ACTIVITY PLUS INITIAL AND TERMINAL OPERATIONS.

[3] INCLUDES THE TIME REQUIRED FOR EXPERIMENT PREPARATIONS, OPERATIONS AND POST ACTIVITY.

[4] CALCULATED BY DIVIDING THE 'TOTAL ENERGY PER MISSION' [1] BY THE 'CYCLES PER MISSION'.

[5] CALCULATED BY DIVIDING THE 'TOTAL EXPERIMENT ELAPSED TIME' [3] BY THE 'CYCLES PER MISSION'.

	CCTV CAMERA	●	●	●	●		●		●				1	.23	.09	.09	2.3	.008	-	30	-
	CAMERA CONTROL UNIT	●	●	●	●	●	●		●				1	.40	.15	.21	7.7	.013	-	30	-
	FRAME STORAGE UNIT	●	●	●	●	●	●		●				1	.46	.09	.43	9.1	.018	-	125	-
	MONITOR	●	●	●	●	●	●		●				1	.46	.34	.52	20.7	.081	-	140	-
	SLOW SCAN SYN & [illegible]	●	●	●	●	●	●		●				1	.46	.09	.09	2.3	.001		-	-
	NUCLEAR PARTICLE COUNTING UNIT G25E						●				●		1	52	21	.49	22.7	.054	-	100	1K
	OSCILLOSCOPE C18E	●	●	●	●	●	●		●				1	.30	24	46	13.6	.033	-	100	-
	TIME LAPSE/HIGH SPEED CAMERA G22E, L44E		●	●	●		●				◉	●	1	.30	30	46	13.6	.041	100	100	-
ENCLOSURES, FURNACES	CHEST GENERAL PURPOSE ENCLOSURE F3E, G26E, L4E			●	●	●				●	●	◉	2	46	46	46	22.7	097	-	-	-
	GLOVE BOX B30E, G3E	●					●	●			●		1	61	61	1 22	45 4	454	-	-	-
	GRADIENT FURNACE F20E					●				●			1	30	61	30	45 4	055	9000*	5000*	-
	HOT WALL FURNACE (1800°C) F2E, L2E			●	●	●				◉		●	1	30	.61	.30	45.4	055	9000*	5000*	-
	HOT WALL TUBE FURNACE (1200°C) F1E, G1E, L1E				●	●				●	●	●	1	30	61	.30	45 4	055	1600*	800*	-
	THERMAL OVEN G2E, L3E		●				●				◉	●	1	30	30	.46	22.7	041	300	300	-
HEAT FLUX MONITOR	DIRECTIONAL CALORIMETER L22E			●		●						●	1	15	15	15	13 6	003	3	3	10
HEATING UNITS	ELECTRON BEAM SOURCE L7E			●	●							●	1	15	15	15	2 3	003	-	5000*	-
	LASER SOURCE L9E			●	●	●						●	1	[illegible]	61	91	36[illegible] 9	339	-	5000*	-
	MICROWAVE HEATER F19E, G4E, L11E			●	●	●				●	●	◉	1	46	45	46	68 0	.097	2000*	200*	50
	MINIMUM B WITH RF HEATING L13E			●	●	●						●	1	.30	.30	.30	4.5	027	2000*	200*	10
	RF INDUCTION COILS L6E			●	●	●						●	2	15	15	15	4 5	003	- *	2000*	-
	RESISTANCE HEATER (CONTACT) F18E, G27E					●				◉	●		1	06	05	15	1 4	001	- *	- *	-
	RESISTANCE HEATER (NON-CONTACT) L5E			●	●	●						●	1	15	15	.15	4 5	003	- *	- *	-
MANIPULATION AND DISPLACEMENT UNIT	FEED & CRYSTAL HOLDER F11E, L28E			●		●				●		●	1	15	91	15	15 9	020	100	25	20
	PIEZOELECTRIC DRIVE F23E, L27E			●		●				●		●	4	.10	.10	61	9 1	006	50	5	100
	THREE-AXIS MANIPULATOR F22E, L25E			●		●				●		●	2	15	.15	15	4 5	.003	50	50	20
	ZONE REFINER F10E					●				●			1	.30	46	.30	4.5	.041	5000	100-6000	40
MIXING AND DISPERSAL UNIT	ACOUSTIC F6E, L12E		●		●	●				●		●	1	18	.18	18	.9	006	-	50*	-
	ELECTROMAGNETIC F7E, L13E		●		●	●				◉		●	1	18	18	.18	9	006	-	50*	-
	MECHANICAL F21E					●				●			1	03	03	03	2 3	.000	100	25	02
OPTICAL EQUIPMENT	DARK FIELD ILLUMINATOR B22E, G11E	●	●				●	●			●		1	05	03	03	2 3	.000	10	10	10
	DYE LASER/FLASH LAMP B6E, G9E, L24E	●	●	●	●		●	●			◉	●	1	1 22	31	31	90.7	117	1000	50-1000	20
	IR SPECTROMETER G8E		●								◉		1	30	91	15	45 4	.041	200	200	20
	LASER OPTICAL SCATTERING MONITOR B4E, G6E, L23E	●	●	●	●		●	●			●	◉	1	30	61	15	11.3	.027	200	200	-
	RETROREONSTRUCTION HIGH RESOLUTION HOLOMICROSCOPE B7E, G10E, L25E	●	●	●	●		●	●			●	●	1	30	30	46	13 6	041	50	50	-
	UV-VIS SPECTROMETER B5E, G7E	●	●					◉			●		1	30	61	21	45 4	.038	200	200	20
POWER CONDITIONING	HIGH VOLTAGE (5KV) B21E	●						◉					2	28	.19	19	9.0	.010	200	20	20
	HIGH VOLTAGE (17KV) F27E, G20E, L41E				●	●				●	◉	●	1	30	30	30	27 0	027	6000	100-6000	20
	LOW VOLT/HIGH AMP F15E, G24E, L42E			●	●	●				◉	●	●	1	.30	.46	46	40 8	063	9000	4000	20
	RF INDUCTION (2KHz - 2MHz) F29E, L39E			●	●	●				●		◉	1	.30	.30	30	16 0	027	2000	200	30
	RF INDUCTION (MIXING & DISPERSAL) F14E, L40E		●		●	●				◉		●	2	.15	.15	15	2 7	003	250	25	20
	VACUUM PUMP POWER CONDITIONER F30E, L47E			●		●				◉		◉	1	.52	18	49	13 6	.046	1000	100	-
SAMPLE PLACEMENT AND RETRIEVAL	INERTIAL INJECTOR L31E			●		●	●					●	1	12	12	15	9	002	10	1	02
	LIQUID SYRINGE DISPENSER G15E, L30E			●							●	●	1	03	03	30	5	.000	50	10	02
	MECHANICAL L29E			●		●	●					◉	1	.03	03	.30	5	.000	-	-	-
	SOLID SAMPLE STORAGE L33E			●	●	●						●	1	**	**	**	**	**	-	-	-
	SPECIMEN/SAMPLE SUPPLY TANKS B20E	●						◉					14	.05	.05	.05	45	.000	-	-	-
	VACUUM CATCH TUBE L32E			●		●	●					●	1	06	06	.15	9	.000	-	-	-
	WASTE LIQUID TANK B26E	●						◉					1	21	.42	.42	4 5	.037			
TEMPERATURE MEASUREMENT AND CONTROL	IR PYROMETER F8E, L20E			●	●	●				●		●	1	.30	.30	.30	9.1	.027	20	20	2000
	LASER PYROMETER F9E, L21E			●	●	●				●		●	1	15	61	15	11 3	014	200	200	2000
	RESISTANCE THERMOMETER		●	●	●	●	●	●		●	●		**	**	**	**	**	**	-		-
	THERMOCOUPLES		●	●	●	●	●	●		●	●	●	**	**	**	**	**	**	-	-	-
	TWO-COLOR PYROMETER F16E, L19E			●	●	●				◉		◉	1	30	30	30	9 1	027	20	20	2000

NOTES

(a) CIRCLED DOTS INDICATE ITEMS USED IN THE CORRESPONDING MINIMUM EQUIPMENT SUBELEMENT

(b) PEAK POWER IS THE VALUE OVER AND ABOVE SUSTAINED POWER

(c) FIGURES IMMEDIATELY AFTER THE EQUIPMENT ITEMS PROVIDE A REFERENCE FOR EACH PIECE. THE FIRST LETTER REFERS TO THE SUBELEMENT ("B" FOR BIOLOGICAL, ETC.), THE DIGITS REFER TO THE NUMBER WITHIN THE SUBELEMENT AND THE LETTER "E" INDICATES AN EQUIPMENT ITEM

*FROM POWER CONDITIONER

**AS REQUIRED

Compiled under "SPACE PROCESSING APPLICATIONS PAYLOAD EQUIPMENT STUDY" performed for George C. Marshall Space Flight Center by TRW Systems Group under Contract No. NAS8-28938, Personnel involved Mr. K. R. Taylor, NASA COR, Mr. R. I. Hammel, Project Manager, Ms. A. Smith, Editor.

22.7				
27.4	.084	700	-	-
2.3	.002	-	30	-
7.7	.013	-	30	-
9.1	.018	-	125	-
20.7	.081	-	140	-
2.3	.004	-	[illegible]	-
22.7	.064	-	100	1K
13.6	.033	-	100	-
13.6	.041	100	100	-
22.7	097	-	-	-
45 4	454	-	-	-
45 4	055	9000*	5000*	-
45.4	055	9000*	5000*	-
45 4	055	1600*	800*	-
22.7	.041	300	300	-
13 6	003	3	3	10
2.3	.003	-	5000*	-
362.9	.339	-	5000*	-
68 0	097	2000*	200*	50
4 5	.027	2000*	200*	10
4 5	003	- *	2000*	-
1 4	001	- *	- *	-
4 5	003	- *	- *	-
15 9	.020	100	25	20
9 1	006	50	5	100
4 5	.003	50	50	20
4 5	041	5000	100-6000	40
9	.006	-	50*	-
9	.006	-	50*	-
2.3	000	100	25	02
2 3	.000	10	10	10
90 7	.117	1000	50-1000	20
45 4	.041	200	200	20
11.3	.027	200	200	-
13 6	.041	50	50	-
45 4	038	200	200	20
9.0	.010	200	20	20
27 0	.027	6000	100-6000	20
40.8	063	9000	4000	20
16.0	.027	2000	200	30
2 7	.003	250	25	20
13.6	046	1000	100	-
9	.002	10	1	02
.5	.000	50	10	02
5	000	-	-	-
**	**	-	-	-
.45	.000	-	-	-
9	.000	-	-	-
4.5	037			
9.1	.027	20	20	2000
11.3	014	200	200	2000
**	**	-		-
**	**	-		-
9 1	.027	20	[illegible]	2000

REMARKS

[1] ADD THE 'TOTAL ENERGY PER MISSION' FOR EACH INDIVIDUAL SUBELEMENT TO THE ENERGY NEEDED BY THE CORE. THE CORE ENERGY IS DETERMINED BY ADDING 1HR. (FOR INITIAL AND TERMINAL OPERATIONS) TO THE RESPECTIVE 'TOTAL EXPERIMENT ELAPSED TIME' [3] AND MULTIPLYING THIS BY THE POWER LEVEL OF THE CORE (1.8KW).

[2] INCLUDES THE TIME REQUIRED FOR EXPERIMENT PREPARATIONS, OPERATIONS AND POST ACTIVITY PLUS INITIAL AND TERMINAL OPERATIONS.

[3] INCLUDES THE TIME REQUIRED FOR EXPERIMENT PREPARATIONS, OPERATIONS AND POST ACTIVITY.

[4] CALCULATED BY DIVIDING THE 'TOTAL ENERGY PER MISSION' [1] BY THE 'CYCLES PER MISSION'.

[5] CALCULATED BY DIVIDING THE 'TOTAL EXPERIMENT ELAPSED TIME' [3] BY THE 'CYCLES PER MISSION'.

[6] PEAK POWER IS THE DIFFERENCE BETWEEN THE 'AVERAGE POWER' [7] AND THE HIGHEST POWER LEVEL THAT OCCURS WITHIN THE PAYLOAD COMBINATION.

[7] CALCULATED BY DIVIDING THE 'AVERAGE ENERGY PER CYCLE' [4] BY THE 'DURATION PER CYCLE AT AVERAGE POWER' [5].

[8] SUSTAINED POWER IS THE TYPICAL POWER LEVEL THAT OCCURS DURING THE EXPERIMENT OPERATIONS AND EXCLUDES EXPERIMENT PREPARATIONS AND POST ACTIVITY TIMES. IT IS CALCULATED BY ADDING THE SUSTAINED ENERGIES OF THE RESPECTIVE SUBELEMENTS AND CORE AND DIVIDING BY THE SUM OF THE EXPERIMENT OPERATIONS TIMES OF THE SUBELEMENTS.

[9] CONSISTS OF THE TOTAL FOR THE EQUIPMENT ITEMS PLUS AN APPROPRIATE FACTOR TO ALLOW FOR SUPPORTING STRUCTURES OR EXTRA SPACE.

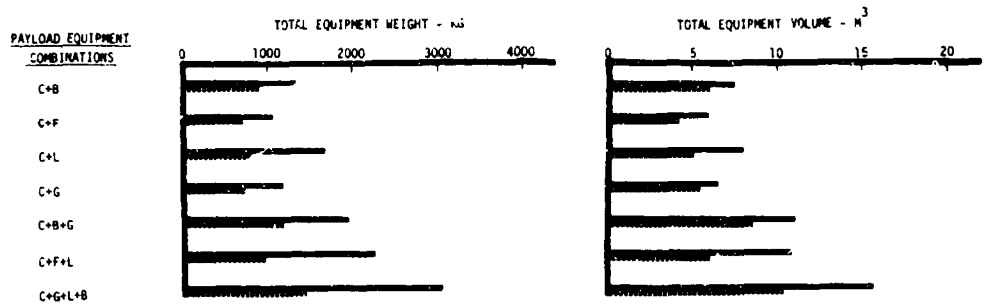
[10] CONTINUOUS.

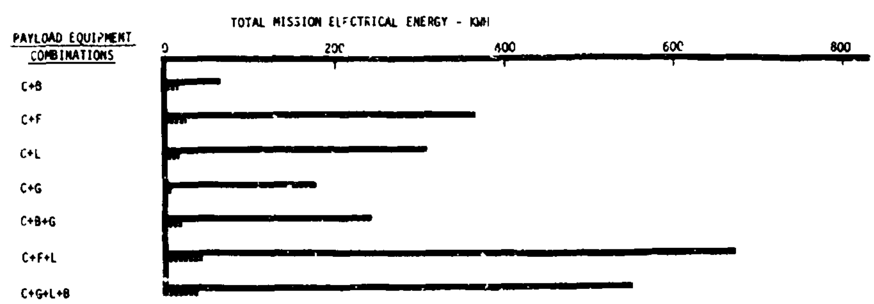
[11] DEPENDENT UPON PAYLOAD COMBINATION BEING CONSIDERED.

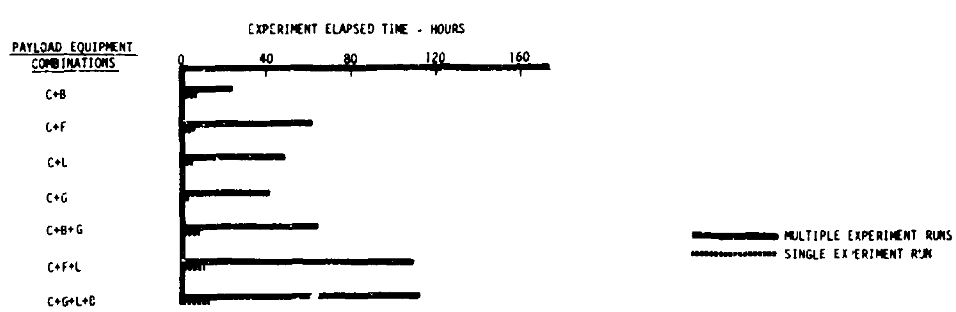
MINIMUM SUBELEMENT DEFINITIONS

b - SEPARATION OF BIOLOGICALS EXPERIMENT
f - IMMISCIBLE SOLIDIFICATION EXPERIMENT
g - RADICAL LIFETIMES EXPERIMENT
l - GLASS PREPARATION EXPERIMENT

COMPARATIVE ANALYSIS OF SELECTED SPA EQUIPMENT SUBELEMENTS







FOLDOUT FRAME 4

TABLE III

RESULTS OF THE STUDY OF EXPERIMENT
CLASSES BY RESEARCH AND DEVELOPMENT CATEGORY

BIOLOGICAL PROCESSES

- Bio-Growth of L-Phase Organisms.*
- Dialysis, including fermentation dialysis.*
- Electrophoretic separation and dielectrophoretic separation of cells, serums, proteins, etc.
- Growth of bacterial cultures.*
- Lyophilization.
- Protein separation by isoelectric focusing.*

CHEMICAL PROCESSES IN FLUIDS

- Controlled study of chain reactions affected by convection.*
- Electrochemical research of surface reactions and novel methods of electro-synthesis.
- Electron spin resonance experiments on free radicals.*
- Investigations of the mechanisms of liquid-solid and gas-solid catalysis using the nonconvection effects of weightlessness to study the intermediates present at the catalytic surface.
- Polymer research including: dynamics of initiation, extrusion techniques, optical quality plastics, interactions in stero-specific polymers, homogeneous dispersal of particles in a polymer matrix and controlled polymerization from selected initiation sites.

*Experiment class added during the experiment/equipment review.

TABLE III (cont'd)

- Study of chemical kinetics including: free radicals, modified flow systems, excited state life times, heterogeneous interface kinetics and wall effects.
- Study of liquid crystals.
- Study of the synthesis of compounds including: heterogeneous synthesis from immiscible liquids, improved yields of solid-liquid interactions.

CRYSTAL GROWTH

- Bulk single crystal growth on seed crystals by vapor deposition or chemical vapor deposition.*
- Investigation of whisker growth from a vapor.
- Single crystal pulling experiments from a containerless melt.
- Study of crystal growth in aqueous solutions and flux.
- Study of crystal pulling-molten zone techniques.
- Study of molten zone crystal growth.
- Sphere seeding crystal growth experiments.

GLASS PREPARATION

- Containerless preparation of conventional glasses.
- Examination of pure glass surfaces by laser induced damage.*
- Glass processing for fiber optics.*
- Mixing studies of conventional glass preparations.
- Preparation of new and unique glasses from high melting point (~3000 C) oxides.

METALLURGICAL PROCESSES

- Containerless preparation of ultra-pure alloys.*
- Directional solidfication of eutectics.
- Gas phase dispersion in liquid metals.*
- Investigations of supercooling and homogeneous nucleation.

TABLE III (cont'd)

- Purification of metals by containerless distillation.*
- Purification of metals by zone refining.
- Solidification of immiscible materials and composite materials.

PHYSICAL PROCESSES IN FLUIDS

- Dispersion of particles in a liquid phase.
- Flow visualization studies of suspended particulate.*
- Greater precision in physical property measurements including critical points, surface tension, compressibility, liquid-free volumes and flow effects.
- Investigation of instabilities in containerless liquids.
- Mass transport processes controlled by diffusion.
- Methods of contactless heating of containerless liquids.
- Study of containerless position control of liquids by electromagnetic, electrostatic, gas jet and acoustic methods.
- Study of heat and mass transport in gases.*
- Study of the fluid mechanical means of mixing containerless fluids by electromagnetic, electrostatic, gas jet and acoustic methods.
- Study of surface tension, thermal gradient mixing of liquids (Maragoni effect).
- Study of thermocapillary convection during liquid-solid phase changes.*

3. SURVEY OF LITERATURE

A review was made of documents received concerning completed and ongoing programs addressing the subject of space processing applications for the purpose of identifying additional experiments appropriate for early mission Shuttle flights. This review included new material obtained after the previous report* was submitted, including SPA SR&T efforts initiated by MSFC, Space Shuttle Payload Planning Working Group reports and European planning efforts. The SPA Literature obtained after the previous report was submitted, and not referred to specifically below, is listed in the references.

As with the previous report, not all the experiments reviewed were considered appropriate for early mission studies. Emphasis was placed on early mission research on the behavior of materials in a weightless condition. The criteria used in selecting experiments was the same as with the previous report:

- Experiments on the behavior of materials in space which will aid later SPA programs, particularly in the development of equipment.
- Experiments which may increase our basic understanding of space processing in which a number of factors are studied and which may aid in understanding processing performed on Earth.
- Basic research experiments in biology, chemistry, materials science, physics and other areas of science.

Experiments which would measure only a single parameter for a possible economic advantage in manufacturing, while important to later stages of the SPA program, were considered inappropriate for early Shuttle flights and are therefore not included .

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*Requirements add Concepts for Materials Science and Manufacturing in Space Payload Equipment Study, DCN No. 1-2-21-00172.52, TRW Systems, July 1973.

The additional experiments recommended as a result of this review are listed in Table IV and are discussed in Sections 3.1-3.6. Some of these experiments have been covered in general terms in the previous report*, but there appears to be sufficient interest in the scientific community to note them more specifically - particularly when additional equipment would be required. Items of additional equipment required for these experiments are given in Table V along with information regarding their commonality and summary data. The xenon arc-image heating element is a general purpose heating device that has been recommended by ERNO.

3.1 BIOLOGICAL PROCESSES

3.1.1 Separation of Biological Material by Isotachophoresis

This separation method is similar to electrophoesis and isoelectric focusing in that particle motion in a liquid media is induced by an applied electric field. Interest exists in studying this method in the absence of buoyancy flow convection and settling.

3.1.2 Crystal Growth of Protein-Based Materials

Improved diffusion-controlled crystal growth methods for protein-based materials such as DNA and enzymes are of interest for more precise structure determinations by X-ray diffraction methods.

3.1.3 Aerosol Microbiology

This is an example of a method of studying cells and microorganisms under conditions not obtainable on earth. Cultures within small liquid droplets would be suspended in a controlled gaseous atmosphere containing nutrients allowing greater uniformity in the growth conditions. Harvesting of the cultures would also be possible accompanied by reduced contamination.

3.1.4 Cryoprecipitation of Biological Material

In the absence of buoyancy flow convection cryoprecipitates fractionated in a temperature gradient at low temperatures would remain in the isothermal plane where they were formed. This method may allow separation of certain biological materials which is not possible by any other means.

*Requirements and Concepts for Materials Science and Manufacturing in Space Payload Equipment Study, DCN No. 1-2-21-00172.52, TRW Systems, July 1973.

TABLE IV

ADDITIONAL EXPERIMENTS

BIOLOGICAL PROCESSES

- Separation of biological material by isotachophoresis [1].
- Crystal growth of protein-based materials [1].
- Aerosol microbiology [1].
- Cryoprecipitation of biological material [1].
- Growth of biological cells in low-G [2].

CHEMICAL PROCESSES IN FLUIDS

- Study of spherical flames under low-G and low pressure conditions [3].

CRYSTAL GROWTH

- Single crystal growth by the Bridgman-Stockbarger method [4].
- Nucleation during crystallization of droplets [2, 5, 6].

GLASS PREPARATION

- Gas phase dispersion in molten glass [7].
- Ceramic compositions produced by chemical vapor deposition [1].
- Controlled eutectic solidification of ceramics [1].
- Purification of ceramic material by containerless distillation [1].

METALLURGICAL PROCESSES

- Formation of thermosetting alloys [8].
- Liquid phase sintering [9].

PHYSICAL PROCESSES IN FLUIDS

- Study of quantum effects in superfluid helium [5, 10, 11].
- Bubble nucleation in a superheated liquid [2, 6].
- Study of heat and mass transfer in liquids [1, 3].
- Study of non-buoyant flow convection [1, 3, 12].

TABLE V. ADDITIONAL SPA EXPERIMENT REQUIREMENTS SUMMARY

EQUIPMENT ITEM	COMMONALITY: R & D CATEGORY: BIOLOGICAL APPLICATIONS	CHEMICAL PROCESSES IN FLUIDS	CRYSTAL GROWTH	GLASS PREPARATION	METALLURGICAL PROCESSES	PHYSICAL PROCESSES IN FLUIDS	SUBELEMENT: BIOLOGICAL	CORE	FURNACE	GENERAL PURPOSE	LEVITATION	SUMMARY DATA: NO. REQD.	DIMENSIONS X(M)	Y(M)	Z(M)	WT. KG	VOL. M^3	POWER (WATTS) PEAK	SUS.	DATA BPS
BIOLOGICAL PROCESS EQUIPMENT																				
CRYOPRECIPITATOR	●						●					1	0.15	0.45	0.15	10	0.01	5	5	-
HEATING UNITS																				
XENON ARC - IMAGE HEATER [6]				●	●				●	●	●	1	0.1	0.4	0.4	0.6	0.02	2200	**	-
OPTICAL EQUIPMENT																				
STROBOSCOPE [2,6]						●				●		1	0.4	0.1	0.1	0.5	0.004	110	10	-

SPA 74-1948

3.1.5 Growth of Biological Cells in Low-G

Some problems with the study of cell growth which occur under conditions at 1-G may be of lesser importance at low-G. There is interest in examining the following with respect to primary cells and cell lines of differing origin: contact inhibition (suspension culture), cell cycles with phase duration, nucleus division, basic metabolism and ultrastructure.

3.2 CHEMICAL PROCESSES IN FLUIDS

3.2.1 Study of Spherical Flames Under Low-G and Low Pressure Conditions

A spherical flame can be produced in low-G by injecting fuel through a porous sphere in a chamber containing the oxidizer. Because the flame structure would have spherical symmetry, a simple analytical description of the flame is possible. Comparison of experimental results with the predictions of the analytical model may result in a better understanding of the chemical kenetics of combustion.

3.3. CRYSTAL GROWTH

3.3.1 Single Crystal Growth by the Bridgman-Stockbarger Method

Although this method may not be as promising for producing perfect single crystals in low-G as other proposed methods, since contact with container walls will exist, it may be useful in early experiments in studying crystal growth in the absence of buoyancy flow convection. Useful results might be obtained while the technical difficulties of position control are worked out on the containerless methods (e.g., Czochralski).

3.3.2 Nucleation during Crystallization of Droplets

Weightlessness is required to achieve the long suspension times necessary for these experiments. An aerosol of liquid droplets (e.g. water) would be suspended in an atmosphere of low vapor pressure. Nucleation and crystallization resulting from cooling by evaporation would be recorded as a function of time and drop size by polarized light or holography. The primary interests in these experiments are in the areas of meteorology and aeronautics.

3.4 GLASS PREPARATION

3.4.1 Gas Phase Dispersion in Molten Glass

The interests in gas phase dispersion in molten glass lies with the study of processing methods in low-G, and with the study of the behavior of a gas phase in molten glass and during solidification.

3.4.2 Ceramic Compositions Produced by Chemical Vapor Deposition

New ceramic compositions may be possible by chemical vapor deposition under the more precisely controlled conditions which will be available in the absence of gravity-induced convection in the vapor phases.

3.4.3 Controlled Eutectic Solidification of Ceramics

As with metallic alloys, directional solidification of ceramic eutectics may yield new composite materials (e.g., Z_rO_2-Al_2O_3) with unique properties. Most of the materials of interest would require high temperatures [$\sim$ 3000 C (5400 F)].

3.4.4 Purification of Ceramic Material by Containerless Distillation

This method has been suggested previously for the purification of metals. The same arguments are valid for ceramic material as well. As with most purification techniques practiced in 1-G, the use of a container introduces measurable amounts of contamination. Other associated problems which can be investigated are the processing of high temperature containerless ceramic melts and methods of separating distilling phases from the melt.

3.5 METALLURGICAL PROCESSES

3.5.1 Formation of Thermosetting Alloys

Thermosetting alloys are intermetallic compounds formed in a mixture of high melting point solid metallic particles in a lower melting point liquid metal (e.g.,the amalgam formed from a mixture of solid silver in liquid mercury used for dental restoration). Certain classes of these alloys are difficult to produce in 1-G because the process is sensitive to the distribution homogeneity (e.g., gallium compounds). Proper distributions may be possible only in low-G.

3.5.2 Liquid Phase Sintering

Processing of liquid phase sintered (LPS) compacts in low gravity has been proposed with the objective of overcoming present limitations on LPS compacts processed on Earth. Effects of gravity-induced settling and convection in the liquid phase will be much smaller in space, allowing a more uniform distribution of particles.

3.6 PHYSICAL PROCESSES IN FLUIDS

3.6.1 Study of Quantum Effect in Superfluid Helium

These are basic research experiments in the physics of fluids with no immediate applications in the near future. The interest lies in studying the properties of superfluid helium in the absence of container walls. For example, superfluid helium drops can be suspended in low-G for the purpose of observing the formation of quantized vortices.

3.6.2 Bubble Nucleation in a Superheated Liquid

Two experimental arrangements are of interest for the study of bubble nucleation in a superheated liquid in low-G: nucleation on treated and on polished transfer surfaces, and nucleation in a superheated liquid bulk during depressurization. The liquid-vapor phase change is affected by gravity within certain limits. For example, volume energies depend on the density difference in the presence of gravity. The effect of gravity can be studied by varying the G-level.

3.6.3 Study of Heat and Mass Transfer in Liquids

Although the contribution to heat and mass transfer in liquids from gravity-induced convection can be taken into account in mathematical models, the models are not subject to test at 1-G. Comparison of models with data taken at low-G may result in more detailed knowledge of molecular motions and non-buoyancy-driven flows. Interest has been expressed in measuring heat transfer coefficients in liquid metals and in water.

3.6.4 Study of Non-Buoyant Flow Convection

The understanding of non-buoyant flow convection will be important in nearly all experiments in low-G involving fluids. What is specifically referred to here are flows arising from surface tension variations, volume

changes due to thermal expansion and pressure variations, and other effects not directly related to externally applied forces from position control apparatus.

4. EXPERIMENTER QUESTIONNAIRES

4.1 APPROACH

In the MS/MS study an analysis of representative experimental activities led to a collection of functional requirements based upon the anticipated nature of such R&D efforts. These require review and updating as the user community continues to develop and as experiment definition SR&T activities proceed. A number of SPA SR&T efforts were initiated by MSFC during the 1972-3 time frame, and such activities and principal investigators (NASA and contractor) provide a base of information to be explored. It is important to establish a dialogue between the payload planning activities and the user community to assure that the discipline remains responsive to the experimenters' needs. It was necessary to establish a baseline of desired information upon which to build this dialogue, therefore, an Experimenter Questionnaire was developed which contains many questions regarding the nature of an experiment. A list of the questions used in this questionnaire is given in Table VI.

These questionnaires were used to obtain information from people who are currently involved in research and experimentation in the various R&D categories. The group that was used as the major source of experimenters was composed of those people who proposed in-space experimentation in the Apollo-Soyuz Test Program (ASTP). A listing of this group is shown in Table VII. These experimenters were contacted in two ways. First, personal interviews were held between some of the experimenters and TRW representatives. A total of 10 interviews were held and those that were interviewed are marked by an asterisk (*) in the Table. At the time of these interviews an attempt was made by the TRW representative(s) to familiarize the experimenter with the concepts of the Shuttle-supported, Space Processing Applications program. During a few of these interviews questionnaires were not completed, but instead the time was spent in an exchange of ideas regarding the program itself.

Secondly, the questionnaire was mailed to the people listed in the Table who were incapable of being reached for an interview. In total, 28 questionnaires were sent out to 26 different experimenters.

TABLE VI

EXPERIMENTER QUESTIONNAIRE

EXPERIMENTER: ____________________

POSITION: ____________________

ORGANIZATION: ____________________

EXPERIMENT TITLE: ____________________

INTERVIEWER: ____________________

DATE: ____________________

1. Briefly, what is the general nature of your experiment?
2. What benefits will be achieved by doing this experiment (i.e., is there a product or process being developed)?
3. Low Gravity Considerations:
   - A. In what manner does the condition of low gravity affect the experiment?
   - B. What G-level is acceptable?
   - C. What length of time is needed in a low gravity environment to fulfill your goals?
   - D. What deleterious effects would result in the event that an acceleration spike occurred during the running of your experiment?
   - E. What G-level could be tolerated during a spike and for how long?
   - F. (Optional) Have you thought of any limits and controls that could eliminate an acceleration spike occurring and insure a stable low gravity environment?
4. Experiment Operations:
   - A. What amount of time would you estimate is required to perform the experiment?
   - B. Give a brief description of the steps involved in performing the experiment and how long each step will take.
   - C. Which of these steps, if any, will be capable of being automated?
   - D. What is the desired sample volume you anticipate and what volume is the minimum acceptable before it causes invalidation of the experiment itself?

     Desired:

     Minimum:

TABLE VI (cont'd)

E. How many experiment runs per mission do you require?

F. What variables will you change in each of these runs?

G. What specialized skills will the crew require to perform the experiment?

H. Will the crew need any special training by you? (If so, please list).

I. Will it be essential that you have real-time contact with the crew during the experiment run time? (If so, during what step(s)?)

J. Can he follow a previously written experiment procedure made by you?

K. How much actual crew time do you think will be required?

5. Environment:

A. Temperature:

1. What maximum temperature will you require for the proper running of the experiment?

2. How much may it vary from this point before the experiment is adversely affected?

Plus__________

Minus__________

3. Will the temperature requirements be relaxed during the non-operating time?

4. What temperature will be acceptable for storage of your samples?

B. Atmosphere:

1. What type of atmosphere will you require during the experiment?

a. Vacuum__________________

Inert Gas________________

Reducing_________________

Oxidizing________________

b. Pressure_________________

c. Other requirements______________

C. Radiation:

1. How will radiation affect your experiment?

2. What level will adversely affect the experiment?

TABLE VI (cont'd)

6. Equipment:

   A. What equipment will you need to perform the experiment?

   B. If you have any particular models or companies in mind, will you please list them here?

   C. Could similar equipment items be substituted for choices listed in "B" above?

   D. Do you know the power levels needed for your equipment listed above? What are they?

7. Physical Characteristics of Experiment:

   A. Can you give us a rough estimate of the weight requirements to handle your equipment needs (including everything you need)?

   B. Approximately what volume would you estimate should be allocated for your experiment?

8. Data:

   A. What data will you need to measure and/or record during the experiment?

   B. Will you be able to make use of an automated data acquisition or control system?

   C. If so, how do you want to handle the data? (Give approximate time period in space).

      1. Real time transmit________________

      2. Store for return________________

      3. Real time display________________

      4. On-orbit dump________________

   D. Will you have need of still or motion picture photography or television monitoring? (If so, during what steps?)

   E. What benefits would be achieved by analyses of the data during the experiment run time?

9. Safety Consideration:

   A. How do you propose to contain your samples?

   B. Does your experimental materials present any special hazards?

   C. What precautions are necessary to protect the crew and equipment in the event that the container broke and the contents escaped?

      1. Will your materials be toxic to the crew?

      2. Will your materials be corrosive to the equipment?

   D. Will the materials be explosive under any conditions?

TABLE VI (cont'd)

E. Will the materials be ...mmable?

F. What special handling is required to prevent problems arising from the previously mentioned hazards?

10. Are there any special handling considerations during launch and reentry?

TABLE VII

PRINCIPAL INVESTIGATORS CONTACTED+

CALIFORNIA

BERKELEY

University of California, Berkeley
Dr. Frank T. Lingren
with
Dr. Hubert J. Peeters (Simon Stevin Institute)
"Viscosity Profile Electrophoresis"

HAWTHORNE

Northrop Corporate Laboratories
Dr. Choh-Yi Ang*
"Influence of Weightlessness on the Immiscibility of Monotectic Alloy Systems"

LOS ANGELES

University of California, Los Angeles
Professor Alfred S. Yue*
and
Professor Cavour W. Yeh
"Zero-G Solidification of NaCl-LiF Eutectic"

PASADENA

Jet Propulsion Laboratory
Dr. Taylor Wang*
"Drop Positioning and Dynamics Experiment"

REDONDO BEACH

TRW Systems Group
Mr. Jo L. Reger*
"Immiscible Systems Processing"

SAN DIEGO

Convair Division of General Dynamics
Dr. Wolfgang H. Steurer*
"Preparation of Superconducting Alloys"
"Spontaneous Resolution of Optically Active Compounds under Zero-Gravity"

+Contacts made via letter unless marked with Asterisk (*).
*Contacted by personal interview.

TABLE VII (cont'd)

TEXAS

BRIAN

Texas A&M University
Dr. W. A. Porters
"The Effects of Zero Gravity on Oxide-Interface Stresses in Silicon"

ALABAMA

HUNTSVILLE

MSFC Process Engineering Laboratory
Dr. Biliyar N. Bhat
"Surface Diffusion in Liquids"

Mr. E. A. Hasemeyer*
"Tin - Cadmium Eutectic Experiment"

MSFC Astronautics Laboratory
Dr. Mary Helen Johnston*
and
Mr. Rudolf C. Ruff
Sintering of Metal Powders"

Dr. R. S. Snyder
"Electrophoresis Technology"

MSFC Space Sciences Laboratory
Mr. T. C. Bannister*
"Convection, Diffusion and Solidification"

University of Alabama in Huntsville
Dr. H. U. Walter
"Seeded, Containerless Solidification of Doped Germanium"
"Solidification Kinetics of Doped Germanium"

Teledyne Brown Engineering
Dr. T. K. Mookerji
"Liquid Phases Sintered Metal Experiment"

Lockheed Missiles and Spa-- Company
Dr. P. G. Grodzka
"Manufacturing in Space Experiments"

Interand Corporation
Mr. R. R. Whymark
"Metal Foaming in Space"

TABLE VII (cont'd)

TENNESSEE

OAK RIDGE

Oak Ridge National Laboratory
Dr. Richard E. Reed
"Study of Surface Tension Induced Convection in Encapsulated Liquid Metals in Zero Gravity"

ILLINOIS

NORTH CHICAGO

Abbott Laboratories, Scientific Divisions
Mr. Grant H. Barlow
"Proposed Experiments for the Zero-Gravity Electrophoretic Isolation by NASA of Urokinase Producing Human Kidney Cells"

Illinois Institute of Technology
Mr. W. B. Crandall
"Space Manufacture of Chalcogenide Glasses for Infrared Optics"

OHIO

COLUMBUS

Battelle Columbus Laboratories
Dr. S. H. Gelles
"Liquid Phase Diffusion Experiment"

Dr. Neal M. Griesenauer
"Undercooling of Materials in Space"

PENNSYLVANIA

LARGE

Westinghouse Research Laboratories
Dr. R. H. Hopkins
"Measurement of Surface Energy of Elements in the Absence of Gravity"

VALLEY FORGE

General Electric Company, Space Science Laboratory
Dr. R. T. Frost
"Supercooling and Nucleation"

Dr. Donald R. Ulrich
"Aqueous Solution Growth of Triglycine Sulfate"
"The Seeded-Melt Growth of Lead Germanate ($Pb_5Ge_3O_{11}$) Electro-Optic Ceramic Crystals"

TABLE VII (cont'd)

MARYLAND

BETHPAGE

Grumman Aerospace Corporation
Dr. D. Larson
with
Professor T. Z. Kattamis (University of Connecticut)
"Role of Convection in Solidification Processes in High Coercive Strength Magnets"

Dr. Herbert D. Kivlign, Jr.
"Glass Nucleation and Crystallization Process in the Near-Zero-G State"

NEW JERSEY

MURRAY HILL

Rensselaer Polytechnic Institute
Professor Herbert Weidemeier
"Crystal Growth from the Vapor Phase in Zero-Gravity Environment"

MASSACHUSETTS

BOSTON

Massachusetts Institute of Technology
Professor H. C. Gatos
and
Professor A. F. Witt
"Quantitative Determination of Zero Gravity Effects of Electronic Materials Processing - Germanium Crystal Growth with Simultaneous Interface Demarcation"

WEST GERMANY

HEIDELBERG

Max Planck Institute fur Biochemie
Dr. Kurt Hannig, Professor
"Electrophoresis Experiment -EPE"

4.2 RESULTS

A total of 16 completed questionnaires were returned for consideration and these are listed in Table VIII.

The responses received were all in the research areas of metallurgical processing (50%), physics of fluids (30%) and crystal growth (20%). None were received for experiments in glass technology, biological applications or fluid chemistry. The data obtained has been compiled into a matrix chart for ease of comparison. This chart is discussed in Section 4.2.1 below. Each of the questionnaires were then condensed into short summaries that are presented later in this report under Section 4.2.2.

4.2.1 Data Matrix

The data matrix shown in Table IX has been organized with the various data parameters listed vertically and experiments listed horizontally by their reference numbers. Part of the chart contains items for which specific values have been estimated by the experimenters. A blank in the chart indicates that either the question was not answered or that a value is not determinable at this time in the estimation of the experimenter. The other part of the chart incorporates bullets to indicate a desirable item whereas a blank indicates the item is unnecessary.

The first four data items concern the subject of acceleration levels. The range of low-G-levels that is desired is from 0.1 G down to 10^{-9}G for periods of from 0.5 hour up to the full 7 days of mission time. The maximum anticipated acceleration spike that is believed tolerable is estimated at 1 G for a period of 1 minute, which was specified for one fluid physics experiment. One will note that about half of the experimenters felt that this problem was not estimative at this time.

The experiment elapsed times of the referenced experiments run from 0.5 hour to the full 7 days. The number of experiment runs per mission is anticipated between 1 and 12. The number of variables to be changed from run to run are listed on the chart and are referenced in Footnotes 6a-o. Probably no more than four variables will be examined during any single experiment. The desired sample volume is what the experimenter

TABLE VIII

LIST OF EXPERIMENTERS
AND RESEARCH AREAS

1. J. L. Reger - "Immiscible Systems Processing"
2. W. H. Steurer - "Preparation of Superconducting Alloys"
3. W. H. Steurer - "Spontaneous Resolution of Optically Active Compounds Under Zero Gravity"
4. M. D. Lind - "Crystal Growth in Zero Gravity"
5. A. S. Yue - "Zero-G Solidification of NaCl-LiF Eutectic"
6. T. Wang, M. Saffren, D. Elleman - "Drop Positioning and Dynamics"
7. H. C. Gatos, A. F. Witt - "Quantitative Determination of Zero-Gravity Effects of Electronic Materials Processing - Germanium Crystal Growth with Simultaneous Interface Demarcation"
8. C. Y. Ang - "Monotectic and Syntectic Alloys"
9. W. A. Porter - "The Effects of Zero-Gravity on Oxide-Interface Stresses in Silicon"
10. B. N. Bhat - "Surface Diffusion in Liquids"
11. R. E. Reed - "Study of Surface-Tension-Induced Convection in Encapsulated Liquid Metals in Zero Gravity"
12. J. M. Tobin - "Measurement of Surface Energy of Elements in the Absence of Gravity"
13. M. H. Johnston - "Sintering of Metal Powders
14. H. U. Walter - "Seeded, Containerless Solidification of Doped Germanium"
15. H. U. Walter - "Solidification Kinetics of Doped Germanium"

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SUSTAINED G-LEVEL (SGL) [g]	10^{-5}	10^{-4}		10^{-4}	0.1-0 4	10^{-4}			10^{-3}	10^{-4}	10^{-3} - 10^{-9}	10^{-3}	10^{-4}	$\leq 10^{-3}$	$\leq 10^{-2}$
TIME AT SGL [HR]	1-24	1	1	24-168	5-6	0.5	3	1	0.5	1-2	4	0.5-1 0	0 5-0.75	2-6	24-48
PEAK G-LEVEL (PGL) [g]	10^{-2}	10^{-3}			0	10^{-2}	(2)		10^{-1}		10^{-3}	1		10^{-2}	10^{-2}
TIME AT PGL [S]	0.1	30			0	0.1	(2)		3	1-2	(3)	60			
EXPERIMENT ELAPSED TIME [HR]	2-25	8	1.5	24-168	6-8	4	4	8	0.5	2	4	3 5	1 5	6-12	24-48
DESIRED SAMPLE VOLUME [CM^3]	10	1000	250	500	20	230,000	7	(5)	85	16	75	5	165		100
MINIMUM ACCEPTABLE SAMPLE VOLUME [CM^3]	1	200	30	500	20	30.000	2		12	2.5	50	0.2	16		100
NUMBER OF EXPERIMENT RUNS PER MISSION	4	3	5	6	6	10	1	3	5-12	1	1	6	3	1	1
NUMBER OF VARIABLES TO BE CHANGED	(6a)	(6a,b)	(6b)	(6c-f)	(6g-j)	(6c,k,l)	(6e m)	[illegible],l)	(6a,b,n)	(6?,b)	0	(6.[illegible]	(6b,c,n)	0	0
CREW TIME NEEDED [HR]	1	3	0.3		0 5	1	0.25	0.5	0 3	1	0.5	0 25	0.25	1	1
MAXIMUM OPERATING TEMPERATURE [C]	200-3500	1700-2400	200	40	950	100	1100	1100	1100	800	700	1000	1100	1200	1200
ACCEPTABLE TEMPERATURE VARIATION [C]	+50 -0	+150 -25	±1	±1	±10		±50	+10 -5	±25	+50 -100	±50		±5		
STORAGE TEMPERATURE [C]	(7)	<16	25	(7)	(7)	<100	[illegible]	≤100	<500		(7)	<95	(7)	(7)	(7)
ATMOSPHERIC REQUIREMENTS (1)	I,R,O	I			V	I	V,[illegible]	V,I		V	V	I	V,I,R	V,I	V,I
ESTIMATED WEIGHT OF EXPERIMENT [KG]	100	70	15	1	10	15	25					20	27	0.5-1 0 (8)	SEVERAL (8)
ESTIMATED VOLUME OF EXPERIMENT [M^3]	1	0 03	0.06	0.001	0.06	0 [illegible]						0.03	0.03	0 001 (8)	0 001 (8)
DESIRED DATA.															
ACCELERATION	●	●	●		●			●			●	●		●	
COOLING RATE	●				●										
FREQUENCY						●									
HEAT TRANSFER															
POSITION						●									
POWER						●							●		
PRESSURE		●													
SHAPE						●							●		
TEMPERATURE	●	●	●		●	●	●	●	●	●	●	●		●	●
TIME	●	●	●				●	●	●	●	●	●			
VIBRATION								●							
DATA ACQUISITION/ CONTROL SYSTEM DESIRED	●	●	●		●	●	●	●		●	●	●	●	●	●
DATA DISPOSITION															
REAL TIME TRANSMIT								100%				15-30%		100%	100%
STORE FOR RETURN	100%	50%			100%	●					100	15-30%	100%	100%	100%
REAL TIME DISPLAY	5%	20%				●						15-30%			
ON-ORBIT DUMP															
PHOTOGRAPHY OR TV MONITORING DESIRED			●	●		●		●							

NOTE: A BLANK SPACE IN THE CHART INDICATES THE QUANTITY IS UNKNOWN AT THIS TIME.

(1) V = Vacuum, I = Inert, R = Reducing, O = Oxidizing

(2) No limit as long as the magnitude and duration are known.

(3) Several minutes

(4) Several days

(5) As large as furnace permits

(6) a-time, b-temperature, c-sample materials, d-pH, e-concentration, f-sample capsule, g-convection level, h-impurity content, i-solidification rate, j-temperature gradient, k-rotation speed, l-sample size, m-chemical nature of dopant, n-packing density

(7) Ambient

(8) Sample and capsule

Table 9. Data Derived From Experimenter Questionnaires

oxidizing atmospheres will be required up to levels of 10 MN/m^2 (100 atm) depending upon the specific experiment. The type needed will be a function of the materials of the capsules and samples and the temperatures to which they will be raised. During storage, all of the examined samples may be kept in a normal cabin atmosphere.

In general, the experimenters were not specific in naming their equipment needs. The most frequently mentioned items were those concerned with raising the temperature of the samples -- furnaces, enclosures, heaters and water baths. Eighty percent of the experimenters desire such equipment, but it must also be observed that the bulk of the research areas considered were in metallurgical processing and crystal growth. These areas do have these requirements. Also related to heating requirements, about 30 percent want temperature measurement, indication and control for the experiment. Active cooling of heated samples was only specified by 13 percent, and one experimenter calls for a dewar for liquid helium storage.

Two experimenters (13 percent of the responses) mentioned a need for atmospheric control (in the process chamber) and two specified a non-contact positioning device. Other equipment mentioned by only one experimenter each included a mixing unit, accelerometers, force transducers, still camera, experiment sequencer, oscillator, power amplifier and current pulsing unit.

By examining these requirements against the list of equipment that was developed previously by this study, it is obvious that no major, new apparatus is needed beyond what has already been anticipated. Specific models were not mentioned by the experimenters, hence, it is not possible to give definitive estimates of powers, energies, weights and volumes for the experiment packages.

All but two of the experimenters expressed a desire to have a data acquisition and control system available. The desired data to be measured and/or controlled is shown on the chart, the most common being accelerations, temperatures and times. About 30 percent of the experimenters

would like to have available for study and these values range from 5 cm^3 (0.3 $in.^3$) up to 0.23 m^3 (8 $ft.^3$). On the other hand, the minimum acceptable sample volume is the least amount the experimenters feel they could use and still obtain valid results. These values range from 0.2 cm^3 (0.01 $in.^3$) up to 0.03 m^3 (1 ft^3).

The crew time needed in all of these experiment areas is minimal compared to the experiment elapsed time. The time periods range from 15 minutes up to 3 hours. In all cases the crew will function without special training directly from the Principal Investigator, but instead will follow a written procedure of the tasks involved. The crew will need, however, to practice the operational check-list for using any automated controls and the data acquisition system prior to flight. This will probably not require the presence of the PI. During flight, real time contact with the crew will normally not be required unless there is an unanticipated malfunction of the equipment. The PI may then wish to make certain changes in parameters in order to salvage the experiment. An example where this would be especially helpful would be in case a detrimental acceleration level occurred during a critical portion of an experiment. The PI on the ground could then advise the crew person what to do to salvage that experiment run. In the case of a solidification experiment, it may be possible to reheat the sample and begin the cooldown phase again.

Several of the data items are concerned with the environmental conditions of the experiment. The maximum operating temperature needed varies greatly. The lowest mentioned was 40 C ($\pm$ 1 C) [100 F ($\pm$ 2 F)] for a crystal growth from solution experiment and the highest mentioned was 3500 C (+50 C; -0 C) [6300 F (+90 F; -0 F] for an immiscible solidification experiment. Ambient cabin temperature will suffice for the storage of samples except in one experiment concerned with the preparation of superconducting alloys where the storage temperature should be kept less than 16 C(60 F).

Several types of atmospheres must be made available for the experiments at varying levels of pressure. High vacuum levels have been requested for about half of the experiments examined. Exact levels were not generally specified except as "best possible". Inert, reducing and

expressed a desire for real time transmission of data and 30% desired real time display (a few want both). Sixty percent of the experimenters also wanted all or part of the data stored until return to Earth. Twenty percent who expressed a desire for a data acquisition/control system did not specify how the data was to be handled, and 30% have need of photography or television monitoring.

It must be reiterated that the functional requirements of the experimenters are dynamic and ever-changing, and a continual update must be maintained to insure that the equipment available fulfills the needs of the scientific community involved with Space Processing.

4.2.2 Catalog of Questionnaire Summaries

Each of the Experimenter Questionnaires have been condensed into short one- to three-page-long summaries in order to eliminate the redundancy of listing the questions each time, while preserving the point of view and, in many cases, the actual words of the experimenter. The information is presented in the same logical order as in the questionnaire. All of the values given are estimates made by the potential investigators, and they are not to be construed as being definitive requirements recommended by TRW Systems Group. These summaries represent a sampling of the field of potential experiments/experimenters and should not be construed as being all inclusive.

4.2.2.1 Immiscible Systems Processing

EXPERIMENTER: J. L. Reger
POSITION: Project Engineer
ORGANIZATION: TRW Systems Group

The purpose of this experiment is to process materials in a low-gravity environment that have a liquid miscibility gap on earth. The benefit of producing these materials in bulk form is to obtain materials that have potentially unique physical and electronic properties. This is not possible on earth since gravity causes density differences and concommitant segregation. The low-gravity environment of space allows these effects to be suppressed. It is desirable to have an acceleration level of 10^{-5} G, however, a level of 10^{-4} G would be acceptable. Experimentally, it has been found that cooling the processed material to its

solidification point at the slowest possible rate enhances the dispersion. Cooldown rates on the order of 1-60 C/min (2-108 F/min) are desirable. If an acceleration spike should occur after processing and during cooldown (before solidification occurs), it would tend to enhance segregation. Cooldown times must be limited to periods when no body forces are imposed upon the spacecraft.

The amount of time necessary to perform the experiment is from 2 hours up to 25 hours. The variation occurs because of the change in cooldown times. The steps involved are as follows:

Heating material to liquefaction	0.75 hours
Process the materials within the consulate temperature range with acoustic or electromagnetic mixing	0.25 hours
Cooldown to solidification	1-24 hours

Cooldown will be slower for glasses and faster for metals. All of the steps may be automated. The crew will not require any special training, but will follow a standardized procedure of the tasks.

The desirable sample size is 100 g (3.6 oz); however, the experiment can be processed with as little as 3 g (0.1 oz). Each experiment will consist of 12 samples being heated to a common temperature. The variable altered will be the cooldown time, which will be changed after each set of three samples are run.

Depending upon the alloy being processed, the maximum temperature needed will be between 200 C (390 F) and 3500 C (6300 F). The variation from the set point that can be tolerated is not presently known. During non-operating times and storage of samples the temperature requirement will be relaxed to ambient room temperature of about 25 C (77 F).

Depending upon the particular alloy being processed, various types of atmospheres will be required: inert, reducing, oxidizing. The pressure needed will range between 10^5 - $10^7 N/m^2$ (1 - 100 atm). There are no restrictions during storage periods.

The equipment items needed to perform this experiment are: low gravity cooling apparatus, heating apparatus, acoustic mixer,

electromagnetic mixer, temperature indicator, non-corrosive containers, accelerometer, waste coolant collector and experiment sequencer. All of these items are commercially available. The items required for the experiment should weight on the order of 100 kg (220 lb) minimum. The assembly envelope should not require a volume over 1 m^3 (35 ft^3).

A data acquisition and control system will be needed to measure and record time, temperature and acceleration level. The entire data accumulated will be stored for return to earth. Real time display will be desired at the startup and end of the experiment which will consist of about 5 percent of the total time. It is not anticipated that there will be any need for photography or television monitoring; however, if a need should arise for it, it will be minimal. In some cases it might be wise to consider minimal analysis of the data in order to guarantee the proper performance of the experiment.

The samples will be encapsulated by inert metals or ceramics. This experiment does pose certain special hazards. First of all, due to the high temperatures achieved during processing, there is the hazard of the crew being burned or certain equipment being damaged should the samples escape during processing. Also, certain heavy metals would be toxic to the crew. These hazards can be prevented by providing a secondary enclosure for the more hazardous materials and for the high temperatures.

These samples will not require any special handling during launch and reentry.

4.2.2.2 Preparation of Superconducting Alloys

EXPERIMENTER: Dr. Wolfgang Steurer
POSITION: Engineering Staff Specialist
ORGANIZATION: General Dynamics - Convair Division

This is a low-G alloying experiment the purpose of which is to produce advanced niobium and vanadium based binary, ternary and quarternary superconducting alloys with transition temperatures above 21 K. If successful, these alloys will have a wide spectrum of applications in electrical equipment and power transmission. This will result in power conservation by the substantial reduction of power losses during transmission.

The condition of low gravity provides two benefits for this experiment. Since accelerations cause these particular alloys to form microsegregations, the condition of low gravity will either reduce or eliminate this problem. Also, in order to produce these alloys on earth, one must acquire specially designed equipment in order to reduce the gravity effects. This equipment is, of course, very expensive. In space, however, one naturally has the low-gravity condition so that the use of commercially available gear will greatly reduce the costs in this area.

It is anticipated that an acceleration level of 10^{-4} G will be required for approximately one hour for each experiment. It is desired to have three runs per mission (for ten missions). This low gravity requirement must be fulfilled during the entire liquid state period. Acceleration spikes up to 10^{-3} G can be tolerated for up to 30 seconds. Anything greater than this level or for longer periods will be unacceptable.

The time period for the running of this experiment should be about eight hours. The crew person (electromechanical technician) will be needed for approximately three hours. A breakdown of the steps involved and approximate times involved for each are as follows:

Apparatus preparation	1.0 hour
Sample installation	1.5 hours
Apparatus checkout	1.0 hour
Heating	1.0 hour
Alloying	0.5 hour
Cooling	2.0 hours
Sample removal and cleanup	1.0 hour

The technician will not need special training, but will simply follow a previously written experiment protocol. Much of the experiment operations will be automated, namely, the heating periods, alloying times and cooling rates.

It is desirable to run the experiment with a sample size of 1000 cm^3 (60 in^3); however, the minimum that could be accepted is about 200 cm^3 (12 in^3).

Depending upon the particular percentage of the constituent elements, the maximum temperature required will be between 1700 C (3100 F) and 2400 C (4350 F). Deviation from the chosen value should not exceed +150 C (270 F) or -25 C (45 F). Exceeding these limits during alloying would invalidate the experiment. The samples will need to be stored at a temperature below 16 C (61 F) maximum value.

During the experiment operations, an inert gas (argon) atmosphere will be required at a level of 150 kN/m^2 (1.5 atm). There are no requirements during non-operating times.

The equipment needed to perform the experiment are: radiation heating furnace, temperature recorder, argon atmosphere controller and either a sample capsule (for 70% of the experiments) or containerless position control device (for 30% of the experiments). It is roughly estimated that the weight required for the apparatuses is about 70 kg (150 lb). The corresponding assembly envelope is estimated at 0.03 m^3 (1.0 ft^3).

There will be a need to make use of an automated data acquisition and control system to record the temperature, time, argon pressure and acceleration level during the G-sensitive time periods. An estimate of the time required for acquisition/control is 4 hours with 1.5 hours of real time display required. If it were found by analysis that an acceleration spike occurred, causing invalidation of the experiment, the sample could be reprocessed prior to return to earth. This would save the time involved in returning a bad sample and waiting to repeat the experiment on a subsequent mission.

The sample materials pose no hazards to the crew or equipment while in the solid form. The furnace enclosure used should be of such design that, if the sample capsule broke or containerless position control failed, the molten material could not escape into the cabin. This design should be consistent with bringing a 1000 cm^3 (60 in^3) sample to 2400 C (4350 F).

The only special handling required during launch and reentry is to store the sample at a temperature below 16 C (61 F).

4.2.2.3 Spontaneous Resolution of Optically Active Compounds Under Zero Gravity

EXPERIMENTER: Dr. Wolfgang Steurer

POSITION: Engineering Staff Specialist

ORGANIZATION: General Dynamics - Convair Division

The purpose of this experiment is to produce sample quantities of optically active compounds by selective crystallization at seed crystals from a solution. The long range goals are to produce certain pharmaceuticals in quantities and degree of perfection not attainable on Earth.

The reason for doing the experiment in space is to provide a low-gravity environment which will eliminate convective disturbances at the crystallization sites and will eliminate sedimentation. It is estimated that a period of one hour per experiment run is required under a stable low-gravity environment. This will be during the heating and cooling steps. Transient acceleration peaks will abuse the product's perfection but will not invalidate the results.

In total, one experiment run should last 1.5 hours. The steps to be followed are listed below:

Sample installation	10 minutes
Heating	15 minutes
Cooling	45 minutes
Sample recovery and storage	20 minutes

All of these steps may be automated. A crew person will be needed for approximately 20 minutes per run. No special training will be required, and a previously written experiment procedure of the tasks will be followed.

The sample volume desired is 250 cm^3 (15 in^3), but the experiment can run with as little as 30 cm^3 (1.8 in^3). It is desired to make five runs having four samples per run, varying the temperature with each run.

The maximum temperature needed for this experiment will be 200 C (390 F); however, most runs will not be over 95 C (200 F). The temperature should not fluctuate but should remain within $\pm$ 1 C (2 F). [illegible]

storage times, the samples should be kept about 25 C (80 F).

Since this experiment utilizes a sealed capsule, there are no atmospheric requirements. In regards to radiation effects, presently defined materials are not affected; however, some future ones may be.

The apparatus needed to perform this experiment is quite simple. The major item is a water bath that is self-contained, involving only fluid systems control. Initially, water temperatures to 95 C (200 F) will be required. The electrical energy needed to perform each run of four samples will be approximately 0.5 kWH. The weight of the experiment package, including all service fluids, will be about 15 kg (33 lb). This will consist of an assembly envelope of about 0.06 m^3 (2 ft^3).

During the performance of this experiment, it will be necessary to utilize a data acquisition and control system to record and control the temperature versus time and G-level versus time. All of the data will be stored for return to earth. Also, a means of making still photographs during the experiment operations is desired.

The samples will be enclosed in specially shaped glass ampoules. The experimental materials present special hazards in some cases. Some materials will be toxic to the crew; therefore, if the sample ampoule should break while in the water bath apparatus, that apparatus should be sealed shut to prevent the sample material from escaping. This, of course, will prevent the continuance of the experiment.

During launch and reentry the only special handling considerations involve the storage of the sample at the appropriate temperature of less than 25 C (80 F).

4.2.2.4 Crystal Growth in Zero Gravity

EXPERIMENTER: Dr. M. D. Lind

ORGANIZATION: North American Rockwell Science Center

The purpose of this experiment is to grow crystals from aqueous solution that are difficult, or impossible, to grow on Earth. Sulfide crystals will be of use as semiconductors, calcite crystals will be of use in optics and halide crystals will be used for optical and electrical applications. At the beginning, emphasis will be directed toward the

growth of sulfide crystals, utilizing the following reactions:

$$Pb^{+2} + S^{-2} \longrightarrow PbS$$
$$Cd^{+2} + S^{-2} \longrightarrow CdS$$
$$Zn^{+2} + S^{-2} \longrightarrow ZnS$$

The reason for choosing these particular reactions is that, on Earth, these materials are only slightly soluble in water which causes the products to precipitate out of solution too fast to allow the growth of large crystals. This is due to the convection forces and gravitational forces that cause rapid mixing of the two solutions and settling of the precipitated powder.

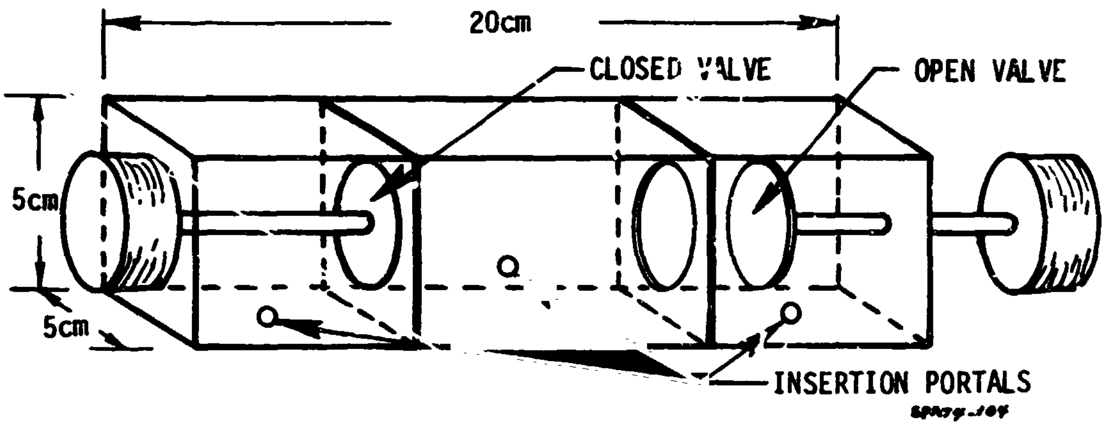
If one performs this experiment in space, the previously mentioned effects can be eliminated. As the crystals are grown in the solution, they will not settle out, but will remain suspended allowing growth of large crystals. It is not known, at present, what level of gravitational acceleration will be required (or tolerated). Acceleration spikes may be tolerated for short periods if they occur perpendicular to the direction of diffusion. If they occurred parallel to that direction, it would cause rapid mixing of the reactants and introduce deleterious effects such as those that occur during convection.

The experiment will run for between 24 hours and 7 days. The procedure followed will be as follows:

Unstow sample reactors	0.1 hour
Attach reactors to supports	0.1 hour
Open valves	0.1 hour
Crystal growth	24 - 120 hours
Store samples	0.1 hour

These steps are very simple and will not require automation. The technician will be able to follow a short written procedure of the tasks.

The process takes place in the following type of container (reactor):



The reactant solutions are kept in the two end sections of the reactor, and the center compartment contains pure water. When the experiment is ready to begin, the valves are opened thereby allowing the reactants to diffuse toward each other. Crystals will begin to grow in the central compartment either by autonucleation or on a seed crystal that has been inserted previously.

It is desirable to process as many sample reactors per mission as possible (about six), but it would be acceptable to fly only one. There are a number of variables that will be changed in the sample reactors. These are: the reactants, the concentrations of the reactants, the pH of the water and the reactor shape (later in the program).

The major advantage in performing this type of crystal growth experiment is that there are no high temperature requirements which means there are no power requirements. The initial experiments will be processed under ambient cabin temperatures of 20-25 C (68-77 F). Later on in the program it may be desirable to process some samples under slightly higher temperatures of up to 40 C (104 F). This will come about when we begin to process reactants that have a greater crystal growth rate at a higher temperature. It will then be necessary to keep the temperature set within about $\pm$ 1 C (2 F). After the crystal growth has been completed, there are no particular temperature requirements.

Very few pieces of apparatus will be needed for this experiment. The sample reactors will be furnished as carry-on equipment. A still

camera will be needed to photograph the crystal growth at regular intervals. There must be, of course, some structural device in which to attach the sample reactors.

The volume of each sample reactor will be approximately 5 cm (2 in) by 5 cm (2 in) by 20 cm (8 in) or 500 cm ($32\ in^3$). The storage compartment for each sample reactor will be slightly larger, about 7.5 cm (3 in) by 7.5 cm (3 in) by 23 cm (9 in), or 1294 cm^3 ($81\ in^3$). Each sample reactor will weigh about 600 g (1.3 lb) and each compartment about 250 g (0.5 lb).

The only data to be recorded will be process time.

The materials used in this experiment will be chosen so that they will be non-toxic to the crew and non-corrosive to the equipment.

In case there is a fracture of the sample reactor, the contents would escape causing a nuisance. It is therefore desirable for them to be attached within an enclosure during process.

These samples will need no special handling during launch and re-entry. After the crystals are grown, they are quite sturdy.

4.2.2.5 Zero-G Solidification of NaCl-LiF Eutectic

EXPERIMENTER: Alfred S. Yue
POSITION: Professor
ORGANIZATION: University of California at Los Angeles

The purpose of this experiment is to prepare a fiber-like eutectic with continuous fibers in the matrix. Also, it is desired to measure the relevant solid state properties of the eutectic. At the present time, studies are being directed towards a NaCl-LiF eutectic, but by the time of the Shuttle-Spacelab flights other eutectic combinations will probably be of interest.

At the present time in the medical field, it is difficult to diagnose certain internal disorders due to inadequacies in X-ray techniques. It is desired, therefore, to develop fiber optics for insertion into the body to observe the disorder. The development of certain fiber-like eutectics will be utilized in medical applications for such image transmission.

On Earth, due to gravitational and convective forces, it is impossible to produce these fibers of the desired length. In space, however, these detrimental forces will be greatly reduced or eliminated and fibers will be grown of greater lengths. It is anticipated that the process will be possible with gravitational forces between 0.1 - 0.4 G. Any acceleration spikes would destroy the continuity of the growing fibers and must be avoided during the entire process time.

The sample material will be contained within an ampoule of about 13 mm (0.5 in.) in diameter by about 15 cm (6 in.) in length. It is desired to process 6 ampoules per mission. Several variables will be changed within the ampoules: impurity content, solidification rate, level of convective currents and the temperature gradient.

The process will consist of the following steps:

Unstow sample ampoule	0.1 hour
Attach to supports	0.1 hour
Heat-up	1 hour
Cooldown	5-7 hours
Remove Ampoules	0.1 hour
Store Samples	0.1 hour

The entire experiment will take about 6-8 hours. It will be possible to automate the heat-up and cooldown phases of the experiment. The crew person will need no special skills to perform the duties, but will merely follow a written procedure. This total involvement with the experiment will be about 0.5 hour.

It is anticipated that the temperatures will range up to about 950 C (1740 F) $\pm$ 10 C (18 F). During the non-operating time there are no special temperature requirements as long as it is below the melting point of the eutectic.

It is desirable to perform the experiment in a vacuum atmosphere at the highest level available in the laboratory.

Radiation will not affect this experiment at all.

The equipment needed to perform this experiment is as follows: multi-purpose furnace, vacuum system, temperature measurement and

control (thermocouples) and a cooling device. None of these items will need to be specially developed. The total volume of the experiment is estimated at about 0.06 m^3 (2 ft^3) and should weign about 9 kg (20 lb).

The data to be recorded will be temperature, cooling rate and G-level. This can be accomplished by using an automated data acquisition and control system. It will be necessary to store the entire data for return to Earth.

The materials to be processed will be chosen so that they will not be toxic to the crew or corrosive to the equipment.

These materials will require no special handling during launch and reentry.

4.2.2.6 Drop Positioning and Dynamics

EXPERIMENTERS: Taylor Wang, Mel Saffren, Dan Elleman
POSITIONS: Senior Scientist, Science Staff, Supervisor, respectively
ORGANIZATION: Jet Propulsion Laboratory

The purpose of this experiment is to perform unique, drop-dynamics experiments in a weightless environment and to develop an acoustical method for controlling and positioning liquids in space. This will lead to the development of a positioning device for Space Processing that will form and control melts under weightlessness. Also, it will lead to a manipulation device for drop dynamics and superfluid drops. The very low G-levels of space (around 10^{-4} G) are absolutely necessary for the success of the experiment. The time needed at this level is anticipated at about 0.5 hour or longer. The occurance of acceleration spikes up to 10^{-2} G for time periods of 0.1 s will not be very serious during the experiment run time.

The whole experiment will take about 4 hours. The steps to be followed are listed below:

- Inject liquids or melts.
- Position by means of an acoustical field.
- Manipulate by means of an acoustical field.

The first two steps are capable of being automated.

It is desirable to have sample sizes of 0.2 m^3 (8 ft^3), but the experiment can be performed with as little as 0.03 m^3 (1 ft^3). The samples will be kept in a storage tube. A total of 10 runs per mission are desired with changes in the following variables: rotation speed, drop size, sample materials.

The crew will require no special skills for this experiment and during early experiments it may be desirable to have real time contact in case the experiment doesn't go according to plan or if unanticipated phenomena are observed. Total crew involvement will be about 1.0 hour.

The temperature range of interest will be between 0 - 100 C (32 - 212 F) during experiment operations. During non-operating times samples should be kept below 100 C (212 F). Atmospheric requirements during experiment operations will be inert gas at an as yet to be determined level. There are no non-operating requirements.

Equipment needed will include an oscillator, a power amplifier and an acoustical driver. These will probably run at about 100 W of power. Total weight and volume requirements will be about 14 kg (30 lb) and 0.2 m^3 (8 ft^3), respectively.

A data acquisition and control system will be required to measure and control the following: temperature, frequency, acoustical power level, equilibrium shape and position of stability of the drop. The data will be stored for return to Earth as well as displayed real time. Also needed will be still or motion picture photography or television monitoring.

4.2.2.7 Quantitative Determination of Zero-Gravity Effects of Electronic Materials Processing-Germanium Crystal Growth with Simultaneous Interface Demarcation

EXPERIMENTERS: H. C. Gatos and A. F. Witt

POSITIONS: Professors

ORGANIZATION: Massachusetts Institute of Technology

The essence of this experiment is the quantitative investigation of growth and segregation behavior (under zero-G conditions) for the system consisting of germanium doped with gallium by using interface demarcation by transmitting periodic current pulses across the growth interface. The following pertinent parameters relevant to future space processing and solidification in general can be quantitatively obtained during post-growth analysis: microscopic growth rate, growth interface morphology and changes throughout the growth, quantitative relationships for segregation on the micro-scale, determination of the diffusion constant for gallium in the germanium melt, quantitative investigation of interface breakdown in the absence of convective interference and others.

The basic intent of this experiment is not to produce a "superior" material, but to perform basic and exploratory research.

The primary recognized effect of low gravity is the absence of convection and decreased contamination from interaction with the confining quartz container. Additional effects are anticipated but are yet to be identified; therefore, they obviously cannot be predicted at this time. The acceptable G-level has not been decided, but it is desired to have it as close to zero as is possible. The amount of time needed under these low-G conditions is estimated at 3 hours.

For this investigation an acceleration spike would be desirable since its effects could be studied in detail. (It would be a transient effect which could be studied since an absolute time reference is given

through interface demarcation.) There is no limitation on the magnitude and duration of the spike as long as the values of such are known.

The total experiment time needed will be about 4 hours. Actual crew time will be about 15 minutes. A brief description of the steps and crew time involved are as follows:

• Insertion of capsule containing semi-conductor	5-7 minutes
• Turn on furnace	1-2 minutes
• Switch over to soaking	1-2 minutes
• Turn on cooldown cycle and demarcation unit	1-2 minutes
• Shut down	1-2 minutes

Temperature readings at 20-minute intervals are desirable but are not mandatory. Any step after the initial sample insertion is capable of being automated. Insertion of the sample cartridge might be done on Earth prior to launch.

This experiment involves "regrowth" so the minimum sample volume needed is 2-3 cm^3 (0.01-0.02 $in.^2$). It would be desirable, however, to process about 7 cm^3 (0.04 $in.^3$). It is planned to have 3 simultaneously performed growth experiments in the furnace. The only possible variable changes will be in the dopant concentration and chemical nature of the dopant.

The maximum temperature required by this experiment is about 1100 C (2000 F), but the actual figure will depend upon the furnace design. It may vary from its stated value by $\pm$ 50 C (90 F). During storage and non-operating times, the only requirement is that it be held below the melting point of germanium which is 948 C (1725 F).

The subject of atmospheric requirements is still under study. It is anticipated that the experiment will require either a vacuum or inert gas atmosphere. During storage there are no special requirements.

Although there are no deleterious effects from anticipated radiation levels, it will be desirable to know the level.

The equipment needed to perform the experiment are as follows: A modified multi-purpose furnace, current pulsing unit (one is being

constructed by Westinghouse) and a millivolt meter for temperature measurement. It is anticipated that 200 W of power will be required during growth with the intermittent (pulsing) load totalling about 500 W/s. It is believed that the equipment will weigh about 23 kg (50 lb).

It will be appropriate to make use of a data acquisition and control system. The data needed will include time and temperature.

The sample materials will b contained within a quartz-ampoule which will be contained within a steel jacket. The materials will not present any hazards to the crew or to the equipment. The materials require no special handling during launch and reentry.

4.2.2.8 Monotectic and Syntectic Alloys

EXPERIMENTER: Dr. Choh-Yi Ang

POSITION: Member Senior Technical Staff

ORGANIZATION: Northrop Research & Technology Center

The purpose of this experiment is to study the solidification from the molten state of Al-Sb (Aluminum-Antimony) and Pb-Zn (lead-zinc) binary systems for the analysis of effects of near-zero gravity on either the degree of immiscibility or homogeneity of the solidified "alloys". This will hopefully lead to the development of potential products with unique properties and also new methods of synthesis.

The difference of specific gravity between antimony and aluminum is about 2.5/1.0 and that between lead and zinc is about 1.6/1.0. The condition of low gravity may alleviate or modify the character of the problems of immiscibility in the lead-zinc and the problems in homogeneous compound formation in aluminum-antimony. It is uncertain what level of low gravity will be required for this experiment, and this cannot be determined until the G-level in Skylab and the results of some similar experiments are known. The low gravity condition will be required for a minimum period of one hour while the materials are in the molten state. An acceleration spike could conceivably ruin the experiment if large microscopic segregation of phases occurs at the initiation of idification of a very small sample. The level at which these deleterious effects would commence or the time periods allowable are

unknown and indeterminable at the present time.

The total time required for the performance of this experiment will be about 8 hours. The following is a list of the steps to be performed for this work:

- Heat to a temperature of 1100 C (2000 F) (with a specially designed region at 850 C (1600 F) in the gradient zone).
- Hold at temperature for two hours.
- Cool down passively

All of the above-listed steps are capable of being automated.

It will be preferred to have at least 3 runs per Space Shuttle mission. As large as possible a sample volume as the furnace will permit will be utilized; however, the experiment will run with as little as 1.0 cm^3 (0.4 in.). The sample materials will be encapsulated in quartz and metal ampoules. The only safety hazard that exists is the very remote possibility of fire hazard should the molten metal escape out of the furnace and contact a flammable object in an oxygen atmosphere. In the various experiment runs the variables to be changed are the rate of controlled solidification and the temperature of the molten metal.

The crew person will be required to have no specialized skills to do this experiment and will follow a written procedure of the tasks. There will be no need for real-time contact with the crew provided that real-time records of flight variables versus experiment run time are available subsequently. It is estimated that not more than 0.5 hour of crew time per experiment run will be required.

There are different maximum temperature requirements depending upon the binary system being studied. The maximum for the aluminum-antimony system is 1100 C (2000 F) and that for the lead-zinc system is 850 C (1560 F). Allowable variations will be within a range of plus 10 C (18 F) and minus 5 C (9 F).

Atmospheric condition requirements for this procedure will include both vacuum and inert gas at levels of 1.3 mN/m^2 (10^{-5} torr) or 100 kN/m^2, respectively. The same requirements will exist for both experiment run

and non-operating times.

The equipment that will be desired for the era of the Space Shuttle will be, not only a larger (than Skylab) electric furnace, but also an induction heater and a levitation/electron beam apparatus. It is impossible, at the present time, to estimate either the weight or volume or power requirements of this apparatus.

It will be necessary to make use of an automated data acquisition/control system for the experiment. The data to be recorded include the following: time/temperature records for the experiment and flight variables such as vibration/acceleration spikes (in real-time with respect to the experiment run time). It will be very desirable to have real-time transmission of the accumulated data. In the case of usage of a levitated-electron beam melting system, we will want to have some type of photography (still, motion picture) or television monitoring during melting and the initial period of solidification.

The handling considerations that exist for this experiment are no more special than those for securing any of the other types of instruments.

4.2.2.9 The effects of Zero Gravity on Oxide-Interface Stresses in Silicon

EXPERIMENTER: W. A. Porter

ORGANIZATION: Texas A & M University

The purpose of this experiment is to examine the effects of oxide interface stresses in silicon. The ultimate objective is to study the feasibility of silicon-device processing in space. It is believed that the low -gravity processing of solid state devices will improve both the devices themselves and the yields obtained.

The condition of low gravity will reduce convection currents in ambient gas from thermal transients and inhomogeneties as well as gravitational stresses in the silicon material. The level that will be needed for this work is no more than 10^{-3}G average. This low level will be required for between 5 to 30 minutes for each of several specimens. The occurrence of acceleration spikes during the experiment run time will probably have negligible effects if the level does not exceed 10^{-1}G for no more than a few seconds.

The experiment will consist of the following procedure.

- Remove quartz ampoule from container and insert into furnace — 2 minutes
- Leave ampoule in furnace at present temperature — 3-25 minutes
- Remove ampoule from furnace, cool in ambient, and replace in container — 5 minutes

The total experiment will take, therefore, between 10-30 minutes for each specimen. The insertion and removal of the sample ampoules from the furnace may be automated by use of a clock-driven push-pull apparatus.

At least six sample ampoules should be processed as a minimum, but twelve would be better. The samples will be sealed in quartz ampoules with a gas fill pressure of 20 kN/m^2 (0.2 atm) or less at room temperature. Ideally, the quartz ampoules should be cylindrical in shape with dimensions of 4 cm (1.5 in.) in diameter by about 8 cm (3 in.) in length; however, these dimensions could be reduced to half these amounts. The variables to be changed from sample to sample are the type of ampoule filler gas, the furnace temperature and the time in the furnace. The crew person will require no special skills or training, but will follow a previously written procedure. The total time involvement will be less than two hours to process all six samples.

The maximum operating temperature that will be reached during the experiment will be 1100 C (2000 F) and a variation of $\pm$ 25 C (45 F) will be tolerated. During all non-operating time periods and storage the temperature requirements will be relaxed to anything less than 500 C (930 F). There are no atmospheric requirements since these samples will be contained within the supplied sample ampoules with the atmosphere being sealed within the ampoule.

The only equipment item that must be furnished is a cylindrical furnace capable of reaching the desired temperature and with a bore big enough to hold the sample ampoule. The specific model is not known presently; therefore, weight and volume requirements cannot be estimated for the equipment. For the quartz ampoules, including container, weight requirements should be about 115 g (4 oz) each. Volume

allocations for the six ampoules in their containers should run about 700 cm^3 (0.25 ft^3).

There will be no need of an automatic data acquisition and control system here. Data that need to be recorded are the furnace temperature and time of exposure in the furnace. It will probably be best to simply write this data on each ampoule container so as to avoid any mix-up in what is required and what is supplied.

No special handling will be required during launch and reentry beyond that of preventing the breakage of the sample capsules.

4.2.2.10 Surface Diffusion in Liquids

EXPERIMENTER: Dr. Biliyar N. Bhat

ORGANIZATION: NASA-MSFC Process Engineering Laboratory

The purpose of this experiment is to determine the surface diffusion coefficients of copper on liquid aluminum and on liquid aluminum-copper eutectic alloy. The information sought is of fundamental importance in that the values have never before been measured. After having been obtained, this information will be useful in analyzing problems involved with solidification.

It is absolutely mandatory to perform these measurements under low-gravity conditions in order to obtain a sufficiently large, undisturbed, free surface under the condition of one-gravity acceleration. We will want as low a G-level as is possible, preferably less 10^{-4}G. A time period of 1-2 hours is needed at this low level. We will want to avoid any accelerating forces during this time period since it could cause convective mixing of undesirable magnitude. Acceleration spikes lasting on the order of 1-2 seconds may not affect the results substantially, but this is not known for sure at this time.

The time required for the whole experiment will be about two hours. The experiment is designed to be performed in a multi-purpose electric furnace. The samples are encapsuled and are introduced into the furnace and melted. The temperature is held for one hour and then the sample is resolidified. Temperature control can be automated in the experiment.

Cylindrically shaped sample cartridges are desired to be 2 cm

(0.8 in.) in diameter by 5 cm (2 in.) in length with a total of 4 samples per cartridge. This requirement can be reduced to 1 cm (1.2 in.) in length with only 2 samples per cartridge. Using the larger cartridges will necessitate only one run of three cartridges per mission to process 12 separate samples. Using the minimum sized cartridge will necessitate more runs per mission to accomplish the same goals, of course. Variables that will be changed from run to run are the time and temperature.

Crew participation will require about one hour, which is for noting the time and temperature accurately. No specialized training will be needed for the performance of the involved tasks.

The maximum operating temperature needed is anticipated to be 800 C (1500 F). Variations of plus 50 C (90 F) or minus 100 C (180 F) from the set point are allowable. During non-operating times there are no special temperature requirements.

A vacuum atmosphere will be required during the running time, and preferably an inert atmosphere during non-operating times. Non-operating requirements are not critical.

The only equipment requirement that exists is an electric furnace such as that produced by Westinghouse for the Skylab missions; however, any type that would function properly would be acceptable.

A data acquisition/control system can be used to record the required data: the temperature as a function of time. This data may be stored until return to Earth or transmitted real time, whichever is best.

There are no special handling requirements associated with this experiment.

4.2.2.11 Study of Surface Tension-Induced Convection in Encapsulated Liquid Metals in Zero Gravity

EXPERIMENTER: Dr. Richard E. Reed

ORGANIZATION: Oak Ridge National Laboratory

The purpose of doing this experiment in space is twofold. Primarily, it is to evaluate the seriousness of surface tension-induced convection in metals under low-gravity conditions. If this turns out to be a substantial problem, one of the previously conceived advantages

of in-space manufacturing will be eliminated. A second advantage accrued from doing this experiment is the acquisition of data regarding the lead-gold (Pb-Au) system. If it is found that convection induced by surface tension is verily negligible over the range of surface tension variations utilized, then several crystal growth experiments become practical that would produce thin crystals of electronic materials.

It is mandatory to perform these investigations in space to achieve as low a gravitational force environment as possible in order to reduce as much as possible the condition of gravity-induced convection. If this condition exists, it masks the effects of the surface tension-induced convection which is under study. Gravitational acceleration levels down to 10^{-3} - 10^{-9}G are needed for a period of approximately 4 hours. Acceleration spikes occurring during the experiment could possibly start convection in the liquid (other than that caused by surface tension) that would make the experimental results highly suspect. Spike levels up to 10^{-3}G could be tolerated for several minutes, but not beyond this.

The total time required for the experiment is approximately 4 hours. The procedure to follow is as follows:

- Load experiment capsules in furnace and set controls.
- Apply thermal treatment.
- Unload experimental capsules and store.

The thermal treatment will be an automated procedure. The desired sample volume is 75 cm^3 (5 $in.^3$), but this could be reduced down to 50 cm^3 (3 in^3). There is only one run anticipated so there will be no variable changes. Crew involvement will amount to about 0.5 hour.

The maximum operating temperature needed will be 700 C (1300 F) with an acceptable variance of $\pm$ 50 C (90 F). During non-operating times the requirements will be reduced to ambient. A vacuum atmosphere will be needed in the furnace during the run time, and ambient cabin atmosphere will suffice at all other times.

The equipment needed for this experiment is an electric multipurpose furnace such as that supplied by Westinghouse for the Skylab

missions. Future experiments, subsequent to the Apollo Soyuz Test Project, should have an electric furnace capable of higher temperatures and faster cooling rates [quenching > 40 C (72 F) per minute]. Total weight and volume requirements are not known for sure since it depends upon the furnace supplied, but it will include six capsules totaling approximately 2 kg (4.4 lb) in weight and 240 cm^3 (15 in^3) in volume.

Data will be handled by use of an automated data acquisition/control system, if available, and will include temperature versus time and acceleration level records. All 4 hours of time/temperature data will be stored for return to Earth since real time analysis is not needed.

All samples to be processed will be non-hazardous to both equipment and crew so no special handling with regard to this is necessary. They will be doubly contained in iron and stainless steel capsules, and no special handling will be required during launch or reentry.

4.2.2.12 Measurement of Surface Energy of Elements in the Absence of Gravity

EXPERIMENTER: Dr. J. M. Tobin

ORGANIZATION: Westinghouse Research Laboratories

The subject experiment is really a multi-purpose system rather than an experiment, per se. This system would be capable of giving measurements of surface tension (interfacial energies) with orders-of-magnitude improvement in sensitivity over those obtained under one-gravity conditions.

The usual method of surface-tension measurement at elevated temperature is to put the forces of surface tension and gravity in opposing directions (as in a sessile drop technique or capillary rise). The absence of gravity eliminates the gradient of hydrostatic pressure, and the force can be measured directly with force transducers. A gravitational level of 10^{-3}G is required for between 0.5-1.0 hour per experiment. The occurrence of limited acceleration load spikes is capable of being analyzed with continuously monitored, force-transducer outputs and can, therefore, be eliminated from the analysis of the whole experiment. The upper load limit would be about 1 G for a period

up to one minute.

The procedure involved and the approximate time required for each step is as follows:

- Load sample 0.1 hour
- Heat to melting 0.5-1.0 hour
- Cooldown 2.0 hour

The heating and cooldown portions will be capable of automation if available. Optimum sample size will be about 0.6 cm (0.2 in.) in diameter by 15 cm (6 in.) in length, but sizes down to 0.15 cm (0.06 in.) in diameter by 5 cm (2 in.) in length can be used. A total of six runs is required for each mission, and each run will consist of a different element or material (alloy, compound, etc.).

The crew will need no specialized skills, but will require some special training by the PI. An operational check list for the automated controls and a data acquisition system must be practiced. Real-time contact with the crew will, therefore, be unnecessary since the written procedure will be available. The total crew time required will be from 1-2.5 hours.

Temperature during operating times will be up to 1000 C (1800 F). No temperature control is required but heating rate control is. During non-operating times, the requirements will be relaxed to between 0-95 C (32-200 F). The atmosphere required during operations is inert gas at 33 kN/m^2 (0.3 atm), and repeated purges of vacuum to inert gas will be necessary. During storage normal breathing atmosphere with no moisture is satisfactory.

Equipment needed to perform this experiment includes a floating zone heating apparatus, force transducers and a data acquisition system (DAS). Power requirements for the furnace and DAS is estimated at 200 W and 50 W DC, respectively. Each of these units will weigh about 10 kg (22 lb) each and occupy about 0.03 m^3 (1 ft^3).

Data to be recorded will consist of force versus real time and temperature versus real time. This data will be transmitted and displayed real time as well as stored for return to Earth. Time required

during each run should range between 0.5-1.0 hour.

The samples consist of solid rods that will not be encapsulated, and there are no hazards associated with the materials that will be used. There are no special handling requirements during launch and re-entry beyond guarding against damage to the equipment and samples due to vibrations and accelerations.

4.2.2.13 <u>Sintering of Metal Powders</u>

EXPERIMENTER: Dr. Mary Helen Johnston

POSITION: S&E - ASTN - MEV

ORGANIZATION: Materials Division, NASA Marshall Space Flight Center

In this experiment, metal powders and oxide powders will be packed and sintered at moderate temperatures. The porosity, strength and sintering mechanisms will be the objects of study. Refractory materials are primarily prepared by this process. It is the purpose of this experiment to show the gravitational influence on the process and to point out the possibility of producing better filters and self-lubricating materials.

Gravity has always been a problem in the packing and settling of powders. Differences in hardness and strength are found along the length and the diameter of sintered materials. The gravitational force and the effect of the container are primarily responsible. A G-level of 10^{-4} is considered acceptable for these studies. The time period required at this level will be between 0.5 - 0.75 hour. Acceleration spikes will be entirely unacceptable during the experiment run time. They would be so harmful that they would most likely nullify the entire experiment.

The entire experiment will take approximately 1.5 hours. The following steps will be included:

- Activate furnace to proper temperature
- Place sample in furnace for 1.0 hour
- Remove sample from furnace

It is believed that the furnace control system will be an automated one.

The sample volume that is desired is 165 cm^3 (10 in^3); however,

the experiment could be performed with as little as 16 cm^3 (1 $in.^3$). The sample will be contained in a box or ceramic crucible. A minimum of three experiment runs per mission will be required. Of course it will be desirable to have as many as possible with variations in materials of composition and packing densities. The variables to be changed from sample to sample will be temperature, material ratios and packing densities.

The crew will require no special skills to perform the required duties but will simply follow a written procedure since no in-space, post-experiment characterization will be required. The total time involvement will be about 0.25 hour.

The maximum temperature required in this experimental area will be 1100 C (2000 F) with a temperature variation of $\pm$ 5 C (9 F) permitted. During non-operating times there are no special requirements, and the samples may be stored at standard cabin temperature.

Atmospheric requirements during the experiment will include the use of vacuum, inert gas and reducing gas. During storage, normal cabin atmosphere will be satisfactory.

Equipment that will be needed will include a furnace, temperature controller and sample storage apparatus. All of this will be off-the-shelf equipment and total weight should be about 27 kg (60 lb). Volume requirements should be about 0.03 m^3 (8 ft^3).

A data acquisition and control system will be needed for this experiment to measure, record and control the temperature and atmosphere. All of the data will be stored for return to Earth. If it is possible to have real time analysis of data, it will provide a means of determining if the equipment is operating properly.

4.2.2.14 Solidification Kinetics of Doped Germanium

EXPERIMENTER: Dr. H. U. Walter

ORGANIZATION: University of Alabama at Huntsville

The purpose of this experiment is to do basic research in the area of dopant redistribution to obtain basic information in the area of space processing and also scientific information about how the condition of low gravity affects the solidification of doped germanium.

The G-levels required will be 10^{-2} or less for a period of 1-2 days which is the total experiment elapsed time. Acceleration spikes during the run would cause no deleterious effects. The steps involved in the experiment have not been determined as yet, but they all will be capable of being automated. A sample size of 100 cm^3 (6 $in.^3$) is desired which will be contained in an inner envelope of quartz and an outer envelope of stainless steel. The total package will weigh several pounds and occupy about 1000 cm^3 (60 $in.^3$). Only one run will be needed and total crew involvement will be about 1 hour. No special skills will be required; therefore, a written description of the procedure will be followed.

The maximum temperature to be needed will be about 1200 C (2200 F) during experiment operations, whereas, ambient cabin temperature will suffice during non-operating times. Vacuum and inert gas will be required at an as yet to be determined level during experiment run times, and normal cabin atmosphere will be adequate for storage of samples.

A gradient furnace will be needed to reach the specified temperature levels and it will run about 250-300 W continuously.

Data acquisition and control equipment will be needed to record and control temperatures by means of thermocouple outputs. The total amount of data will be stored for return to Earth as well as transmitted real time.

The only launch and reentry requirements are to guard against mechanical shock.

4.2.2.15 Seeded, Containerless Solidification of Doped Germanium

EXPERIMENTER: Dr. H. U. Walter

ORGANIZATION: University of Alabama at Huntsville

The purpose of this experiment is to utilize a new, space-adapted, growth technique to achieve basic information on the improvement of structural perfection and dopant homogeneity in the solidification of doped germanium.

The in-space performance of the experiment will reduce convection and permit containerless processing. A G-level of 10^{-3} or less will be

required for between 2-6 hours. An acceleration spike above 10^{-2} will probably cause failure of the experiment.

The experiment will take between 6-12 hours to perform, depending upon the experimental setup that is available at the time, and the whole procedure will be capable of being automated. One run per mission is required. The crew will need no specialized skills and will be needed for about 1 hour.

Temperature requirements will not exceed 1200 C (2200 F) during experiment operations and will be relaxed to ambient cabin temperature during non-operating times. Both vacuum and inert gas will be required at a pressure of 100 kN/m^2 (1 atm) or below, during the experiment time.

The main piece of equipment needed will be a gradient furnace which requires about 250 W of power continuously. The sample will be contained in a stainless steel outer envelope with a quartz inner envelope. The sample plus capsules should weigh about 0.45 - 0.90 kg (1-2 lb) and occupy a volume of about 1000 cm^3 (60 $in.^3$).

An automated data acquisition and control system will be needed to measure and control temperatures (by thermocouples) and acceleration rates. This data will all be stored for return to Earth and also be transmitted real time.

The only special handling consideration during launch and reentry is to guard against mechanical shock.

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